Lysack, W. 1983

1981 and 1982 Cedar Lake Fish Stock Assessment and Changes in Stock Dynamics from 1979 -1982.

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ABSTRACT

As annual commercial quotas and catches of whitefish and walleyes on Cedar Lake have been increasing from 1977 - 1982, stocks have been responding by increasing rates of growth, maturity and recruitment. Whitefish stocks generally seem to be responding faster and to a greater degree than walleye stocks. Proportions of walleyes in commercial catches continue to increase while proportions of whitefish continue to decrease as a direct function of species-specific price differentials. A lack of limited entry control into the Cedar Lake fishery has caused catch per fisherman to decrease since 1979.

TABLE OF CONTENTS

	Page
ABSTRACT	i
INTRODUCTION	1
METHODS AND MATERIALS	1
Experimental Netting	1
Commercial Sampling	3
RESULTS	3
Maturity regimes	3
Growth regimes	3
Age compositions, catch curves and mortality rates from commercial and experimental samples	29
Mesh size effects	29
Changes in walleye and whitefish cohorts and vital parameters from 1979 - 1982	56
CONCLUSIONS AND RECOMMENDATIONS	80
REFERENCES	83

LIST OF FIGURES

Figure		Page
1.	Locations of experimental gang sets in Cedar Lake, 1982	2
2.	1981 maturity curves of Cedar Lake walleyes	8
3.	1981 maturity curves of Cedar Lake whitefish	9
4.	1982 maturity curves of Cedar Lake walleyes	10
5.	1982 Cedar Lake whitefish maturity curves	11
6.	Age-specific mean length-weight relationship of Cedar Lake walleyes, 1981	15
7.	Age-specific mean length-weight relationship of Cedar Lake whitefish, 1981	16
8.	Age-specific mean length-weight relationship of Cedar Lake walleyes, 1982	17
9.	Age-specific mean length-weight relationship of Cedar Lake whitefish, 1982	18
10.	1981 Cedar Lake walleye Walford plots	20
11.	1982 Cedar Lake walleye Walford plots	21
12.	1981 Cedar Lake whitefish Walford plots	22
13.	1982 Cedar Lake whitefish Walford plots	23
14.	Plots of $\log_e (L_\infty - l_t)$ versus t for Cedar Lake walleyes, 1981	25
15.	Plots of $\log_e (L_\infty - l_t)$ versus t for Cedar Lake walleyes, 1982	26

Figure Page

16. Plots of $\log_e (L_\infty - 1_t)$ versus t for Cedar Lake whitefish, 1981 27

17. Plots of $\log_e (L_\infty - 1_t)$ versus t for Cedar Lake whitefish, 1982 28

18. Von Bertalanffy growth curves of Cedar Lake walleyes, 1981 31

19. Von Bertalanffy growth curves of Cedar Lake walleyes, 1982 32

20. Von Bertalanffy growth curves of Cedar Lake whitefish, 1981 33

21. Von Bertalanffy growth curves of Cedar Lake whitefish, 1982 34

22. Exponential growth curve of Cedar Lake walleyes, 1981. 35

23. Exponential growth curve of Cedar Lake walleyes, 1982 36

24. Exponential growth curve of Cedar Lake whitefish, 1981 37

25. Exponential growth curve of Cedar Lake whitefish, 1982 38

26. 1981 age compositions of Cedar Lake walleyes determined from experimental nets and commercial sampling 40

Figure Page

27. 1981 age compositions of Cedar Lake whitefish determined from experimental nets and commercial sampling. 41
28. 1981 catch curves of Cedar Lake walleyes. 42
29. 1981 catch curves of Cedar Lake whitefish 43
30. 1982 age compositions of Cedar Lake walleyes . . . 44
31. 1982 age compositions of Cedar Lake whitefish . . . 45
32. 1982 catch curves of Cedar Lake walleyes 46
33. 1982 catch curves of Cedar Lake whitefish 47
34. Changes in age frequencies of Cedar Lake walleye cohorts 59
35. Changes in age frequencies of Cedar Lake whitefish cohorts 60
36. Growth of Cedar Lake walleye cohorts 61
37. Growth of Cedar Lake whitefish cohorts. 62
38. Temporal changes in commercial catches and annual quotas on Cedar Lake 63
39. Changes in the arithmetic growth rates of Cedar Lake walleye and whitefish stocks 66
40. Changes in exponential growth rates of Cedar Lake walleye and whitefish stocks 67

Figure Page

41. Temporal changes in age-class specific body sizes of Cedar Lake whitefish 70

42. Temporal changes in age-class specific mean body sizes of Cedar Lake walleyes 71

43. Temporal changes in age-class growth responses of Cedar Lake walleye and whitefish stocks 73

44. Temporal changes in instantaneous maturity rates of female walleyes from Cedar Lake 75

45. Temporal changes in instantaneous maturity rates of Cedar Lake walleyes 76

46. Temporal changes in instantaneous maturity rates of Cedar Lake whitefish. 77

LIST OF TABLES

Table		Page
1.	Maturity schedules of Cedar Lake whitefish and walleyes, 1981	4
2.	1982 maturity schedules of Cedar Lake walleyes and whitefish	5
3.	1981 maturity curves of Cedar Lake walleyes and whitefish.	6
4.	1982 maturity curves of Cedar Lake walleyes and whitefish.	7
5.	Age-specific mean lengths and weights of experimentally netted Cedar Lake whitefish and walleyes, 1981	12
6.	Age-specific mean lengths and weights of experimentally netted Cedar Lake walleyes and whitefish, 1982	13
7.	1981 age-specific mean length-weight curves of experimentally netted Cedar Lake walleyes and whitefish	14
8.	Walford curves for Cedar Lake walleyes and whitefish	19
9.	Relationships of $\log_e (L_\infty - l_t)$ and ages of Cedar Lake walleyes and whitefish	24
10.	Cedar Lake exponential and von Bertalanffy growth curves of walleyes and whitefish	30

Table Page

11. Age-specific mean lengths and weights of commercially caught walleyes and whitefish from Cedar Lake, 1981 . . 39
12. Age-specific mean lengths and weights of commercially caught walleyes and whitefish from Cedar Lake, 1982 . . 39
13. Mortality and survival rates of Cedar Lake walleye and whitefish stocks. 48
14. Differences between mean ages of commercially caught fish and mean ages of maturity 49
15. 1980 Cedar Lake walleye mesh size effects 50
16. 1981 Cedar Lake walleye mesh size effects 51
17. 1982 Cedar Lake walleye mesh size effects 52
18. 1980 Cedar Lake whitefish mesh size effects 53
19. 1981 Cedar Lake whitefish mesh size effects 54
20. 1982 Cedar Lake whitefish mesh size effects 55
21. Age-specific frequencies (%) of Cedar Lake walleyes and whitefish determined from experimental and commercial samples 57
22. Age-specific mean lengths (mm) of Cedar Lake walleyes and whitefish determined from experimental and commercial samples 58
23. Catches of Cedar Lake fishermen (pounds) from 1976-1981 64
24. Growth curves of walleye and whitefish stocks in Cedar Lake from 1979 - 1982 68

Table Page

25. Age-class growth responses of Cedar Lake walleye and whitefish stocks 72

26. Maturity curves of Cedar Lake walleye and whitefish stocks 74

27. Temporal changes in instantaneous maturity rates of Cedar Lake walleyes and whitefish 78

28. Recruitment rates of Cedar Lake walleye and whitefish stocks determined from experimental netting and commercial sampling 79

INTRODUCTION

This report presents the results of the third and fourth annual fish stock assessment programs on Cedar Lake. This program was initiated in 1979 in response to continuing requests for quota increases from the Cedar Lake commercial fishermen.

The objectives of this report are:

1. to determine changes in cohort and age class strengths since 1979.
2. to describe maturity, growth and mortality regimes of Cedar Lake walleye and whitefish stocks.
3. to relate changes in the above regimes to trends occurring in the commercial fishery.

METHODS AND MATERIALS

Experimental Netting

In 1981, 6 gangs of gillnets were set in Cedar Lake from July 22 - July 25 and Oct. 7 - Oct. 11. Each gang was set for 24 hours in the locations described by Lysack (1980). In 1982, 8 gangs of gillnets were set in Cedar Lake from June 25 - July 23 and on Sept. 15 (Fig. 1). In both years, each gang was composed of the following meshes: 7.62 cm (3 in.), 8.26 cm (3.25 in.), 9.53 cm (3.75 in.), 10.8 cm (4.25 in.) and 12.7 cm (5 in.). Each net in the gang was 45.72 m long and approximately 1.83 m deep. Walleyes and whitefish caught in the gangs were processed as described by Lysack (1980).

Fig. 1. Locations of experimental gang sets in Cedar Lake, 1982.

Commercial Sampling

In 1981, 250 walleyes and 250 whitefish caught in 4.25 inch nets set by commercial fishermen were sampled on July 1. The fork length (to the nearest 2 mm) and round weight (to the nearest 10 gm) of each fish was recorded. Scale samples from each fish were collected as described by Lysack (1980). In 1982, 250 walleyes and 250 whitefish caught by commercial fishermen were sampled on June 23 as above except dressed weights of whitefish were recorded. Data on species-specific catches were provided by the Freshwater Fish Marketing Corporation.

RESULTS

Maturity regimes

Tables 1 and 2 list the maturity schedules of Cedar Lake walleyes and whitefish for 1981 and 1982, respectively. The maturity curves fitted to the above data are listed on Tables 3 and 4 are depicted in Figs. 2 - 5.

Growth regimes

Age-specific mean lengths and weights of experimentally netted walleyes and whitefish are listed on Tables 5 and 6. Age-specific mean length-weight curves of walleyes and whitefish are listed on Table 7 and are plotted on Figs. 6 - 9. Walford plots are listed on Table 8 and are depicted on Figs. 10 - 13. Plots of $\log_e (L_\infty - 1_t)$ versus t (Table 9, Figs. 14 - 17)

Table 1. Maturity schedules of Cedar Lake whitefish and walleyes, 1981.

Species	Age (years)	No. immature fish			No. mature fish			% mature		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
Whitefish	3	3	0	3	0	1	1	0	100	33.33
	4	9	7	16	1	0	1	10	0	5.88
	5	5	4	9	16	20	36	76.19	83.33	80.00
	6	0	1	1	29	24	53	100	96.00	98.15
	7	2	0	2	12	18	30	85.71	100	93.75
	8	0	0	0	4	4	8	100	100	100
	9	1	1	2	1	1	2			
	10	0	0		1	0	1			
	11	0	0		1	1	2			
	sex ratio	1.54	: 1		0.94	: 1		0.92	: 1	
Walleye	2	1	0	1	0	0	0	0	0	0
	3	0	2	2	0	0	0	0	0	0
	4	5	4	9	3	0	3	37.5	0	25
	5	20	43	63	58	15	73	74.36	25.86	53.68
	6	8	37	45	90	41	131	91.84	52.56	74.43
	7	1	10	11	50	68	118	98.04	87.18	91.47
	8	1	0	1	11	16	27	91.67	100	96.43
	9	0	0		9	6	15	100	100	100
	10	0	0		0	3	3			
	11	0	0		2	2	4			
	sex ratio	.38	: 1		1.48	: 1		1.05	: 1	

Table 2. 1982 maturity schedules of Cedar Lake walleyes and whitefish.

Species	Age (years)	No. immature fish			No. mature fish			% mature		
		Males	Females	Total	Males	Females	Total	Males	Females	Total
Walleye	3	1	2	3	0	0	0	0	0	0
	4	4	6	10	3	0	3	42.9	0	23.1
	5	4	6	10	7	1	8	63.6	14.3	44.4
	6	7	21	28	19	6	25	73.1	22.2	47.2
	7	4	33	37	40	36	76	90.9	52.2	67.3
	8	3	13	16	37	35	72	92.5	72.9	81.8
	9	0	0	0	17	11	28	100	100	100
	10	0	0	0	5	2	7			
	11	0	0	0	1	1	2			
	12	0	0	0	2	0	2			
	sex ratio	.29 male : female			1.43 males : female			.91 males : 1 female		
Whitefish	2	0	3	3	0	0	0	0	0	0
	3	5	2	7	3	0	3	37.5	0	30
	4	2	3	5	4	2	6	66.6	40.0	54.5
	5	2	1	3	3	8	11	60.0	88.9	78.6
	6	0	0	0	4	7	11	100	100	100
	7	0	0	0	1	3	4			
	8	0	0	0	0	1	1			
	10	0	0	0	0	1	1			
	14	0	0	0	0	1	1			
	sex ratio	1 male : 1 female			1.43 males: 1 female			1.25 males: 1 female		

Table 3. 1981 maturity curves of Cedar Lake walleyes and whitefish.

Species	Sex	Maturity curve $-\log_e \left(\frac{k - y}{y}\right) = a + b \cdot \text{age}$	Correlation coefficient	Age at 50% mature (years)	Test F value and d.f.	Age range used in analysis
Walleye	male	$Y = -6.322 + 1.463X$	1.000	4.32	2651.19(1,2)	4-7
	female	$Y = -8.589 + 1.485X$	0.992	5.78	60.99(1,1)	5-7
	combined	$Y = -5.452 + 1.101X$	0.999	4.95	1007.93(1,3)	4-8
Whitefish	male	A. $Y = -15.794 + 3.396X$	1.000	4.65	26963.42(1,1)	4-6
	female	B. $Y = -5.830 + 1.493X$	1.000	3.90	1160.89(1,1)	5-7
		C. $Y = -14.830 + 2.914X$	0.929	5.09	12.61(1,2)	4-7*
	combined	D. $Y = -9.142 + 1.903X$	0.839	4.80	4.76(1,2)	4-7

Table 4. 1982 maturity curves of Cedar Lake walleyes and whitefish.

Species	Sex	Maturity curve $-\log_e (\frac{k - y}{y}) = a + b \cdot \text{age}$	Correlation coefficient	Age at 50% mature (years)	Test F ratio and d.f.	Age range used in analysis
Walleye	male	Y = -3.187 + .734X	.981	4.34	78.18(1,3)	4-8
	female	Y = -6.785 + .968X	.988	7.01	84.5 (1,2)	5-8
	combined	Y = -3.678 + .636X	.982	5.78	79.17(1,3)	4-8
Whitefish	male	Y = -1.638 + .458X	.730	3.58	1.14(1,1)	3-5
	female	Y = -6.835 + 1.675X	.963	4.08	12.79(1,1)	4-6*
	combined	Y = -4.085 + 1.074X	1.000	3.80	1610.96(1,1)	3-5

* 6 year old age class was assigned a mature frequency of 95%

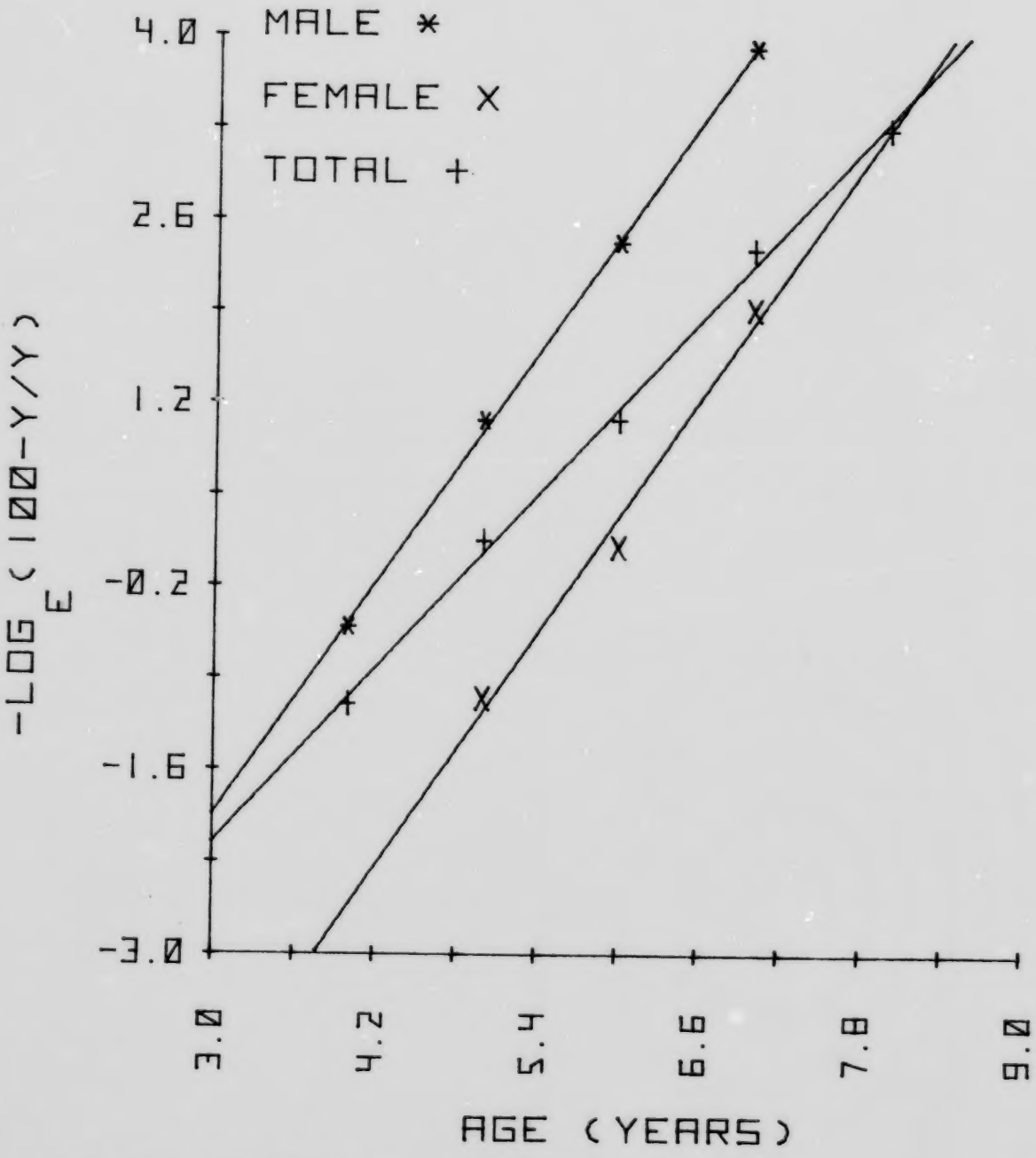

Fig. 2. 1981 maturity curves of Cedar Lake walleyes.

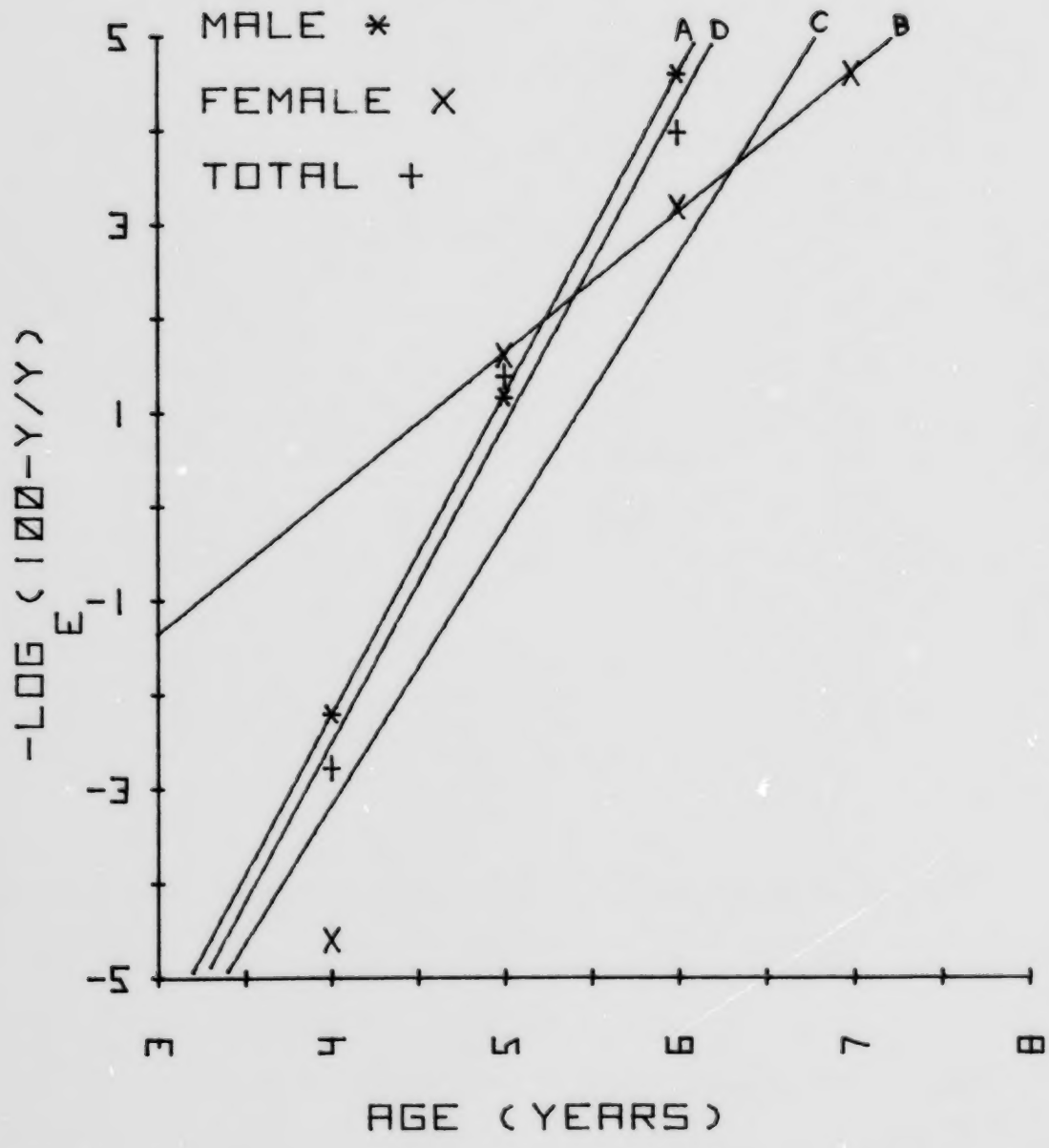

Fig. 3. 1981 maturity curves of Cedar Lake whitefish.

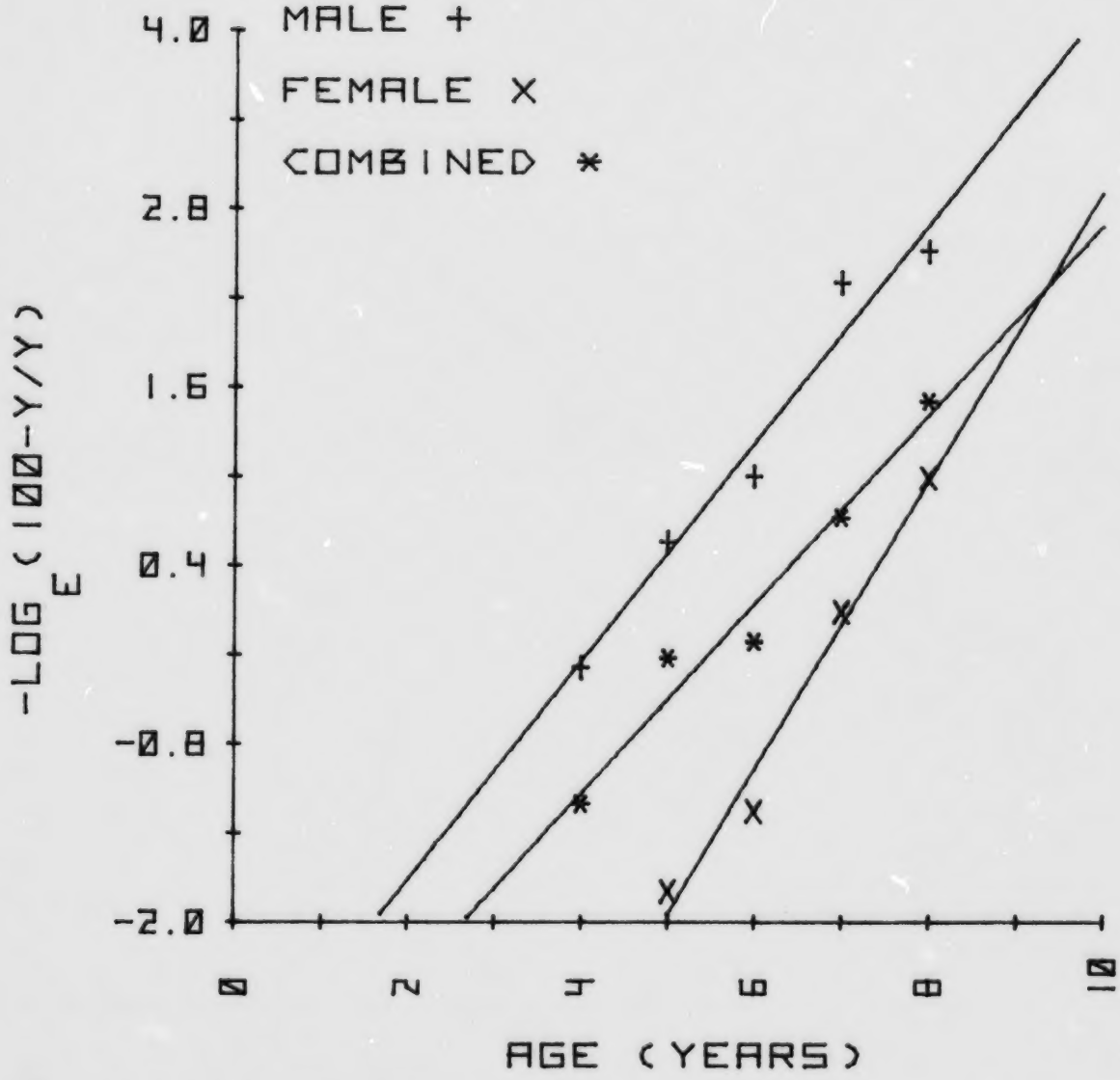

Fig. 4. 1982 maturity curves of Cedar Lake walleyes.

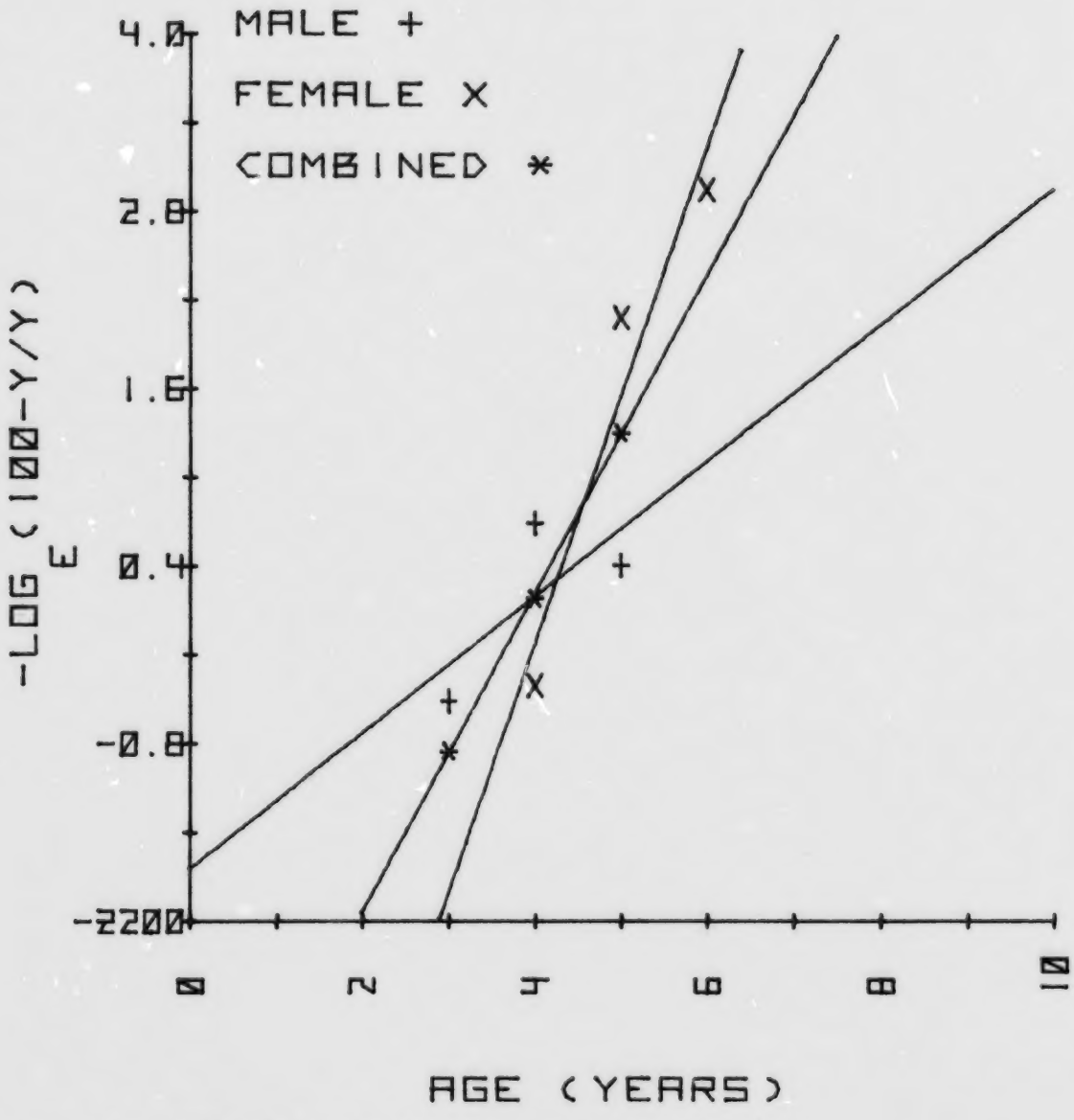

Fig. 5. 1982 Cedar Lake whitefish maturity curves.

Table 5. Age-specific mean lengths and weights of experimentally netted Cedar Lake whitefish and walleyes, 1981.

Species	Age (years)	Mean length (mm)	1 Standard deviation	Mean weight (gm)	1 Standard deviation	No. fish
Whitefish	3	361.00	59.21	845.00	450.30	4
	4	380.47	22.38	967.06	174.78	17
	5	430.58	42.64	1465.11	378.31	45
	6	472.30	27.42	1940.74	432.19	54
	7	500.50	24.03	2395.63	425.20	32
	8	503.75	33.95	2450.00	430.28	8
	9	469.50	116.00	2110.00	1112.89	4
	10	568.00	-	3440.00	-	1
	11	609.00	21.21	3790.00	183.85	2
Walleye	2	290.00	-	380.00	-	1
	3	350.00	2.83	520.00	28.28	2
	4	354.67	28.61	523.33	119.95	12
	5	393.87	28.27	731.76	178.76	136
	6	422.88	31.52	932.67	230.84	176
	7	453.48	34.62	1201.16	294.53	129
	8	486.93	37.86	1496.79	406.89	28
	9	496.93	45.34	1640.00	535.16	15
	10	552.00	24.25	1986.67	320.21	3
	11	561.00	66.48	2405.00	622.33	4

Table 6. Age-specific mean lengths and weights of experimentally netted Cedar Lake walleyes and whitefish, 1982.

Species	Age (years)	Mean length (mm)	1 Standard deviation	Mean weight (gm)	1 Standard deviation	No. fish
Walleye	3	292.00	67.62	313.33	185.83	3
	4	349.38	27.87	520.00	110.75	13
	5	377.00	42.18	672.22	226.81	18
	6	398.72	33.82	780.75	191.75	53
	7	436.11	32.01	1018.94	258.18	113
	8	453.52	33.68	1145.45	267.74	88
	9	489.79	41.84	1457.86	356.12	28
	10	512.57	27.00	1634.29	207.75	7
	11	570.00	50.91	2280.00	537.40	2
	12	520.00	16.97	1690.00	98.99	2
Whitefish	2	288.67	20.13	373.33	64.29	3
	3	322.80	44.69	622.00	213.01	10
	4	386.73	57.52	1138.18	445.28	11
	5	424.14	28.69	1462.86	329.46	14
	6	445.27	25.94	1783.64	311.49	11
	7	483.00	18.94	1820.00	469.61	4
	8	472.00	-	2280.00	-	1
	10	508.00	-	2720.00	-	1
	14	558.00	-	2820.00	-	1

Table 7. 1981 age-specific mean length-weight curves of experimentally netted Cedar Lake walleyes and whitefish.

Species	Year	Length-weight relationship	R	Test F ratio and d.f.
Walleye	1981	$\log_e$ weight = -10.705 + 2.907 $\log_e$ length	0.991	439.33(1,8)
	1982	$\log_e$ weight = -11.063 + 2.960 $\log_e$ length	1.000	22745.34(1,8)
Whitefish	1981	$\log_e$ weight = -10.936 + 3.006 $\log_e$ length	0.994	588.11(1,7)
	1982	$\log_e$ weight = -11.721 + 3.136 $\log_e$ length	0.985	229.95(1,7)

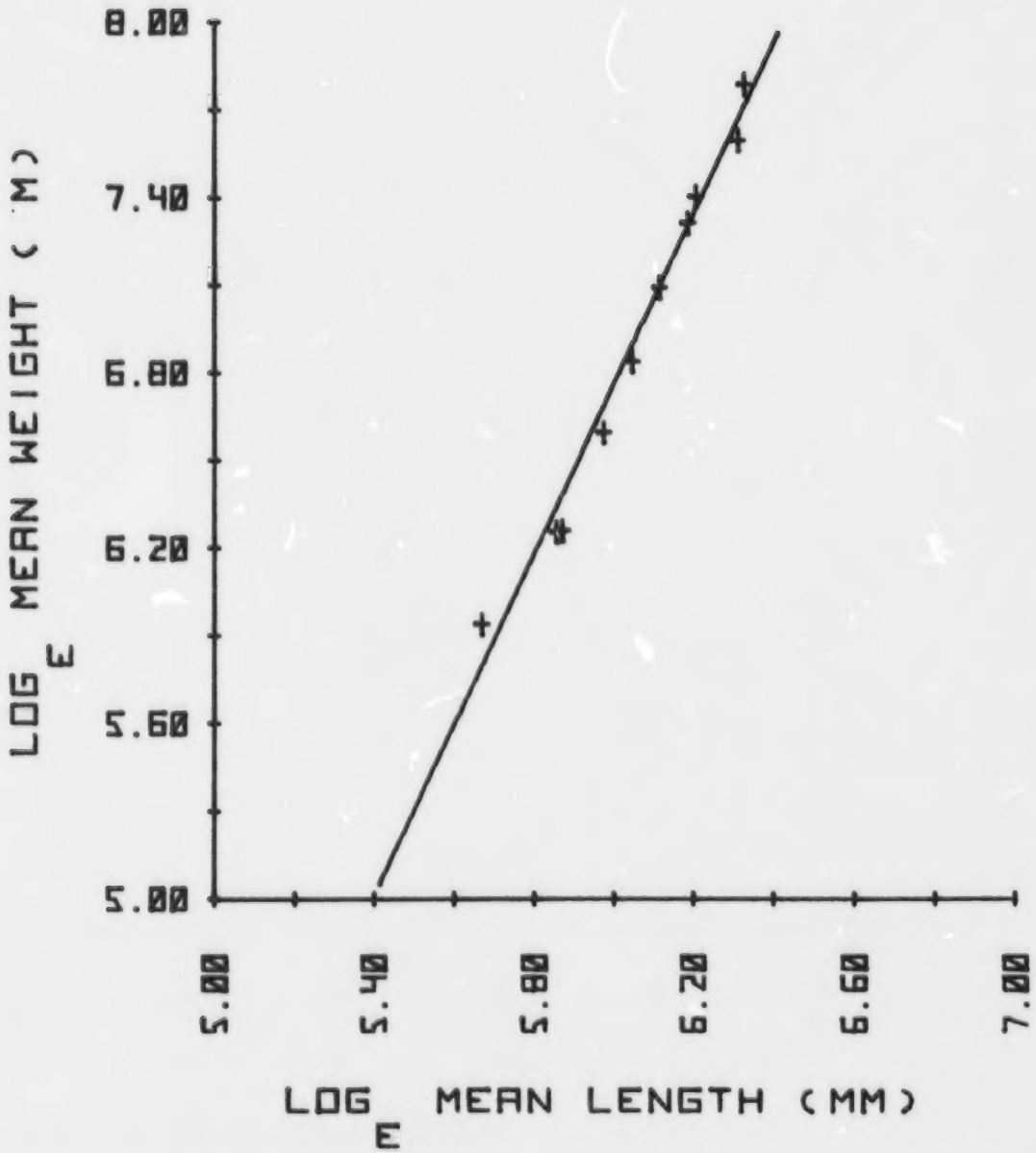

Fig. 6. Age-specific mean length-weight relationship of Cedar Lake walleyes, 1981.

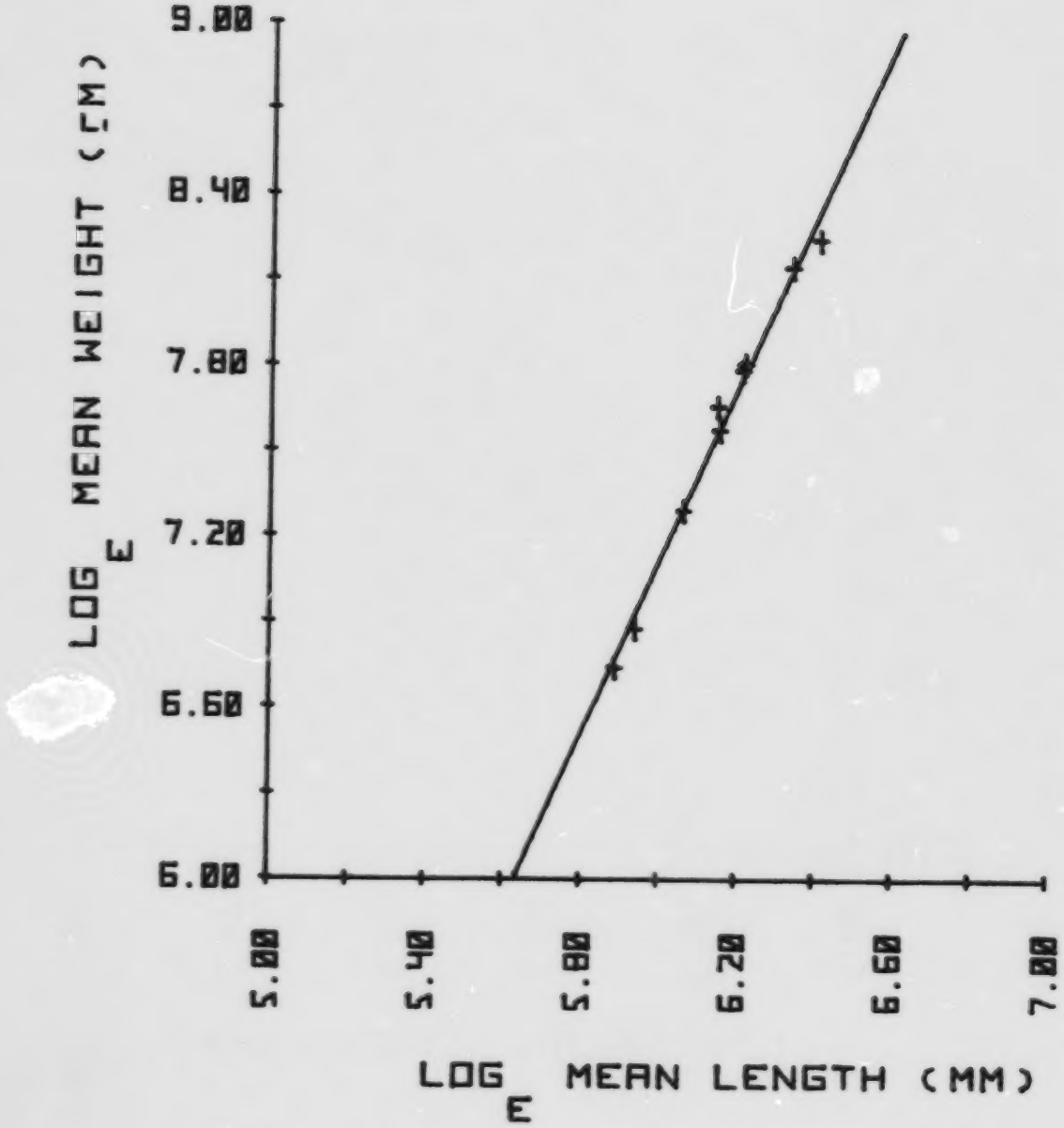

Fig. 7. Age-specific mean length-weight relationship of Cedar Lake whitefish, 1981.

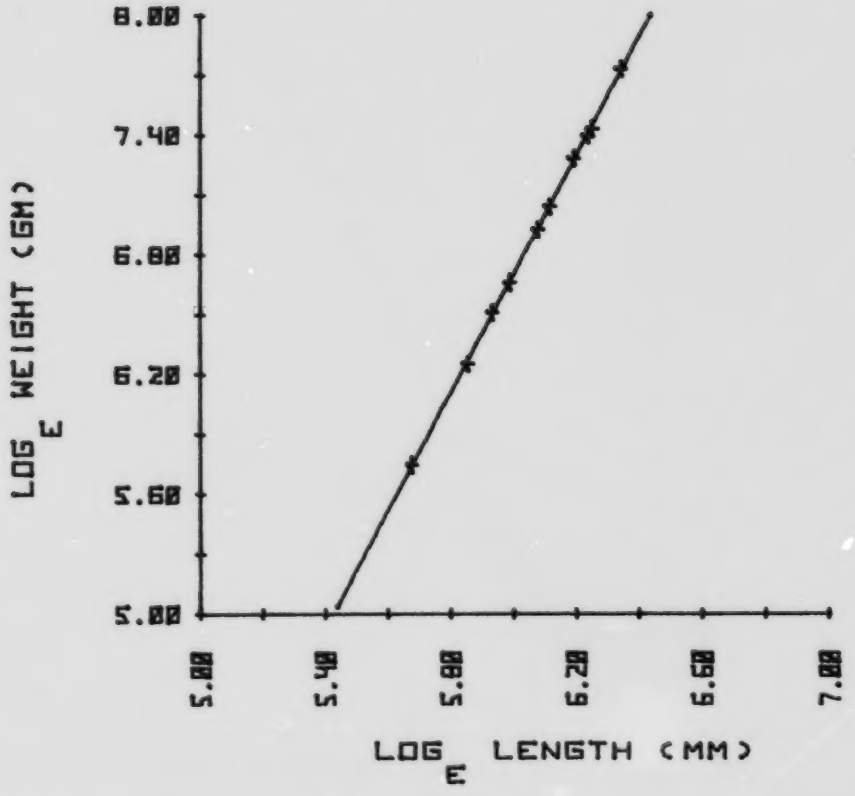

Fig. 8. Age-specific mean length-weight relationship of Cedar Lake walleyes, 1982.

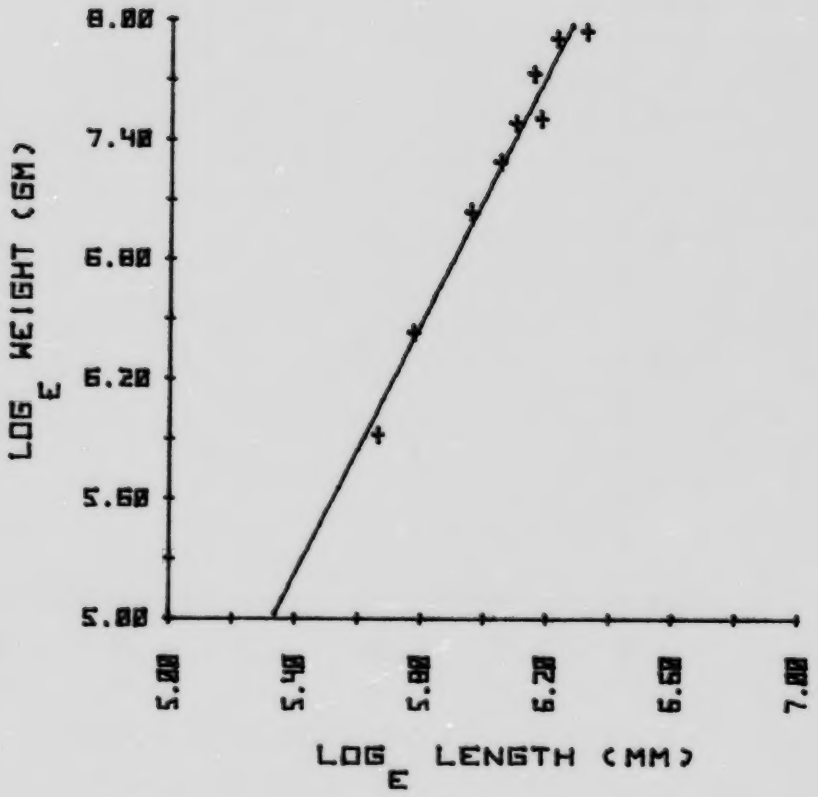

Fig. 9. Age-specific mean length-weight relationship of Cedar Lake whitefish, 1982.

Table 8. Walford curves for Cedar Lake walleyes and whitefish.

Species	Year	Walford curve	L_∞	Ages deleted	R	Test F ratio and d.f.
Walleye	1981	$L_{t+1} = 66.299 + .914L_t$	770.92	-	.972	120.61(1,7)
		$L_{t+1} = 99.767 + .831L_t$	590.34	2-4,9-11	.987	117.56(1,3)
	1982	$L_{t+1} = 116.210 + .789L_t$	550.76	-	.934	48.16(1,7)
		$L_{t+1} = 150.975 + .693L_t$	491.78	3-4,10-11	.936	35.08(1,5)
Whitefish	1981	$L_{t+1} = 73.396 + .908L_t$	797.78	-	.853	16.00(1,6)
		$L_{t+1} = 97.098 + .840L_t$	606.86	9-11	.953	29.46(1,3)
		$L_{t+1} = 194.296 + .633L_t$	529.42	3-4,8-11	.977	41.92(1,2)
	1982	$L_{t+1} = 121.498 + .768L_t$	523.70	-	.956	42.03(1,4)
		$L_{t+1} = 195.324 + .599L_t$	487.09	2-3	.946	25.51(1,3)

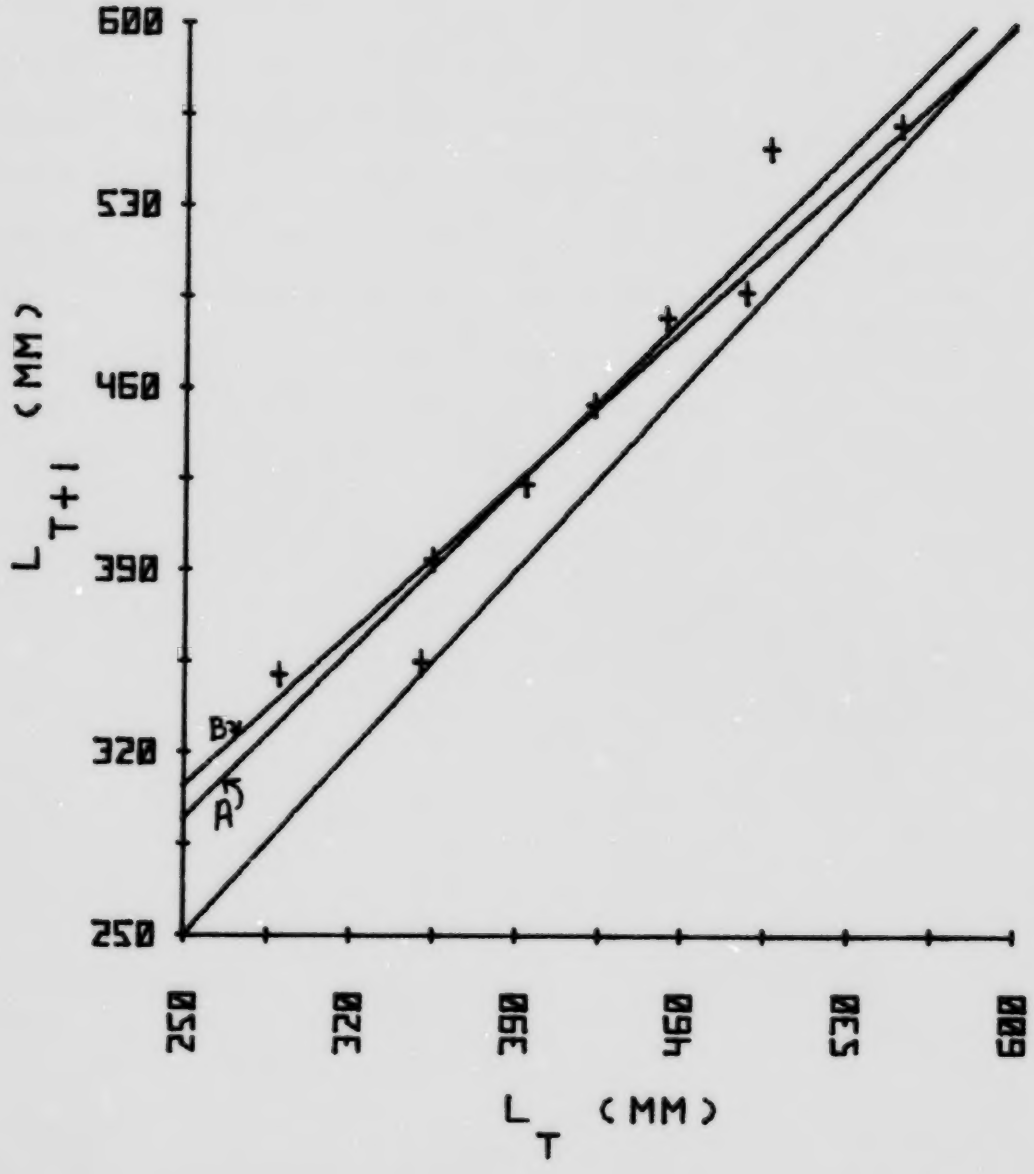

Fig. 10. 1981 Cedar Lake walleye Walford plots. Curve A - including all points, curve B - deleting first, second, eighth and ninth points.

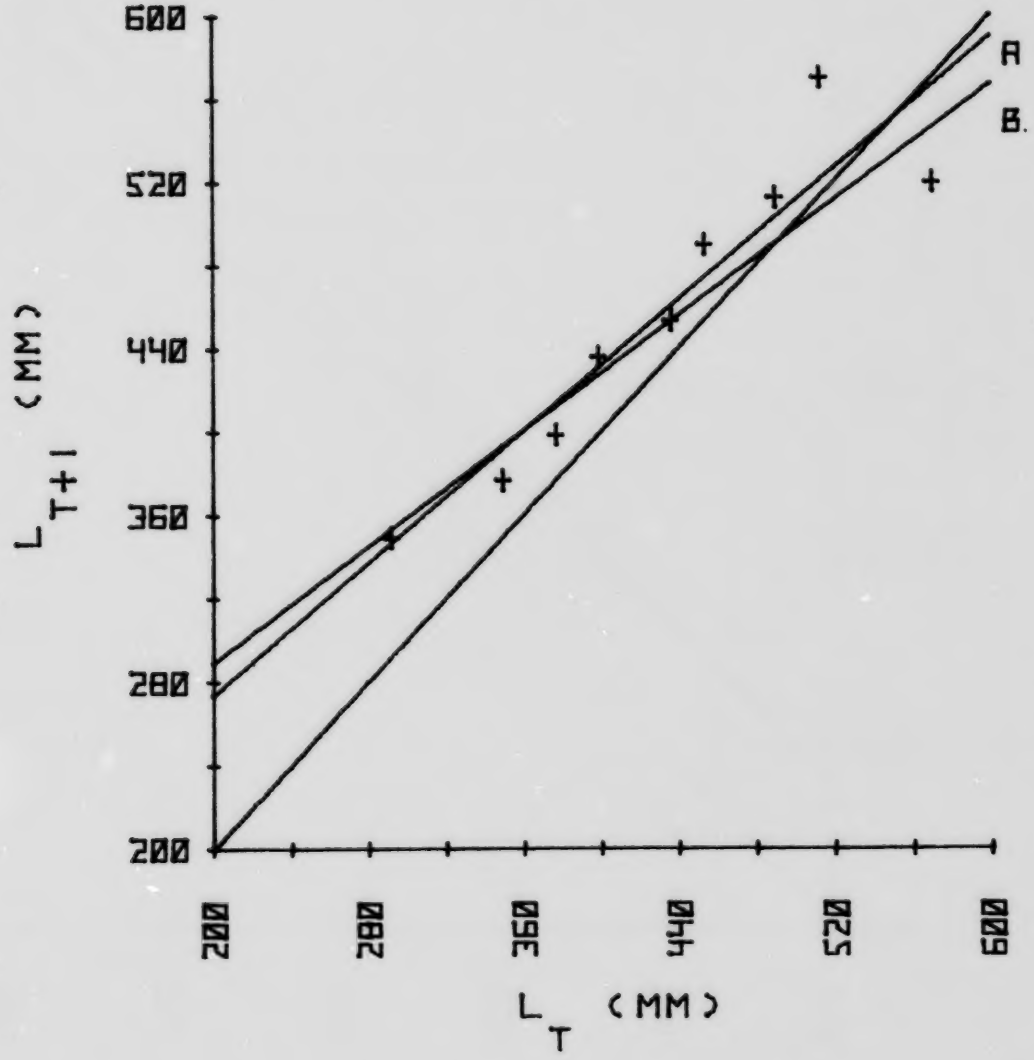

Fig. 11. 1982 Cedar Lake walleye Walford plots. Curve A includes all points, curve B - deleting first and seventh points.

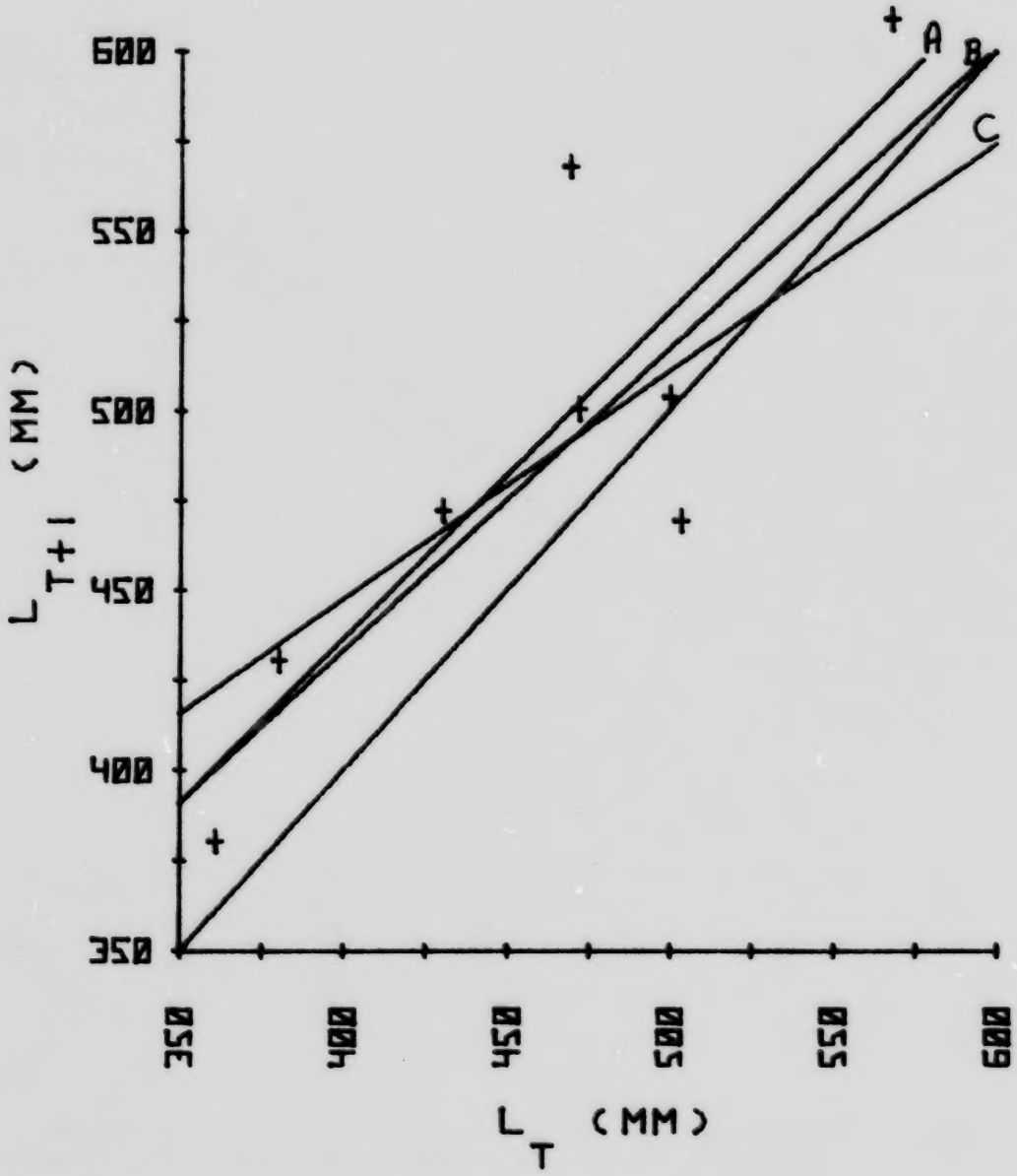

Fig. 12. 1981 Cedar Lake whitefish Walford plots. Curve A - all points, curve B - deleting ages 9 - 11, curve C - deleting ages 3 - 4, 8 - 11.

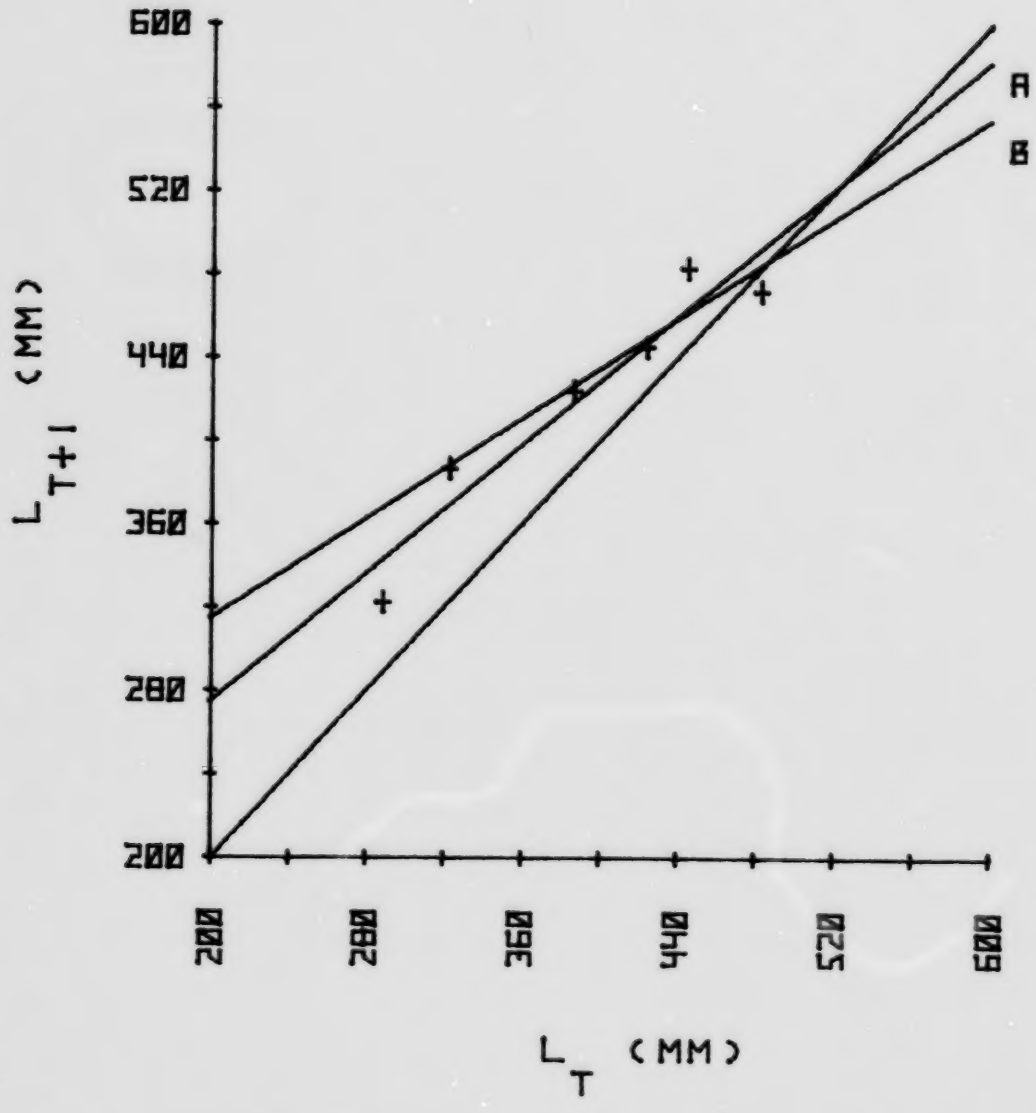

Fig. 13. 1982 Cedar Lake whitefish Walford plots. Curve A - includes all points, curve B - deleting first point.

Table 9. Relationships of $\log_e (L_\infty - l_t)$ and ages of Cedar Lake walleyes and whitefish.

Species	Year		$\log_e (L_\infty - l_t) = a - b \cdot t$	Ages deleted	R	Test F ratio and d.f.
Walleye	1981	A.	$\log(770.92 - l_t) = 6.373 - .091t$	-	.989	365.00(1,8)
		B.	$\log(590.34 - l_t) = 6.415 - .246t$	-	.950	74.59(1,8)
		C.	$\log(590.34 - l_t) = 6.073 - .169t$	10,11	.989	265.02(1,6)
	1982	A.	$\log(550.76 - l_t) = 6.420 - .255t$	-	.975	117.42(1,6)
		B.	$\log(491.78 - l_t) = 6.307 - .323t$	9,10	.989	176.50(1,4)
Whitefish	1981	A.	$\log(529.42 - l_t) = 6.567 - .425t$	9-11	.980	98.97(1,4)
		B.	$\log(606.86 - l_t) = 6.132 - .197t$	9-11	.983	112.12(1,4)
		C.	$\log(797.78 - l_t) = 6.378 - .091t$	-	.927	42.85(1,7)
	1982	A.	$\log(523.70 - l_t) = 6.235 - .329t$	14	.979	140.06(1,6)
		B.	$\log(487.09 - l_t) = 6.321 - .440t$	7,14	.995	395.36(1,4)

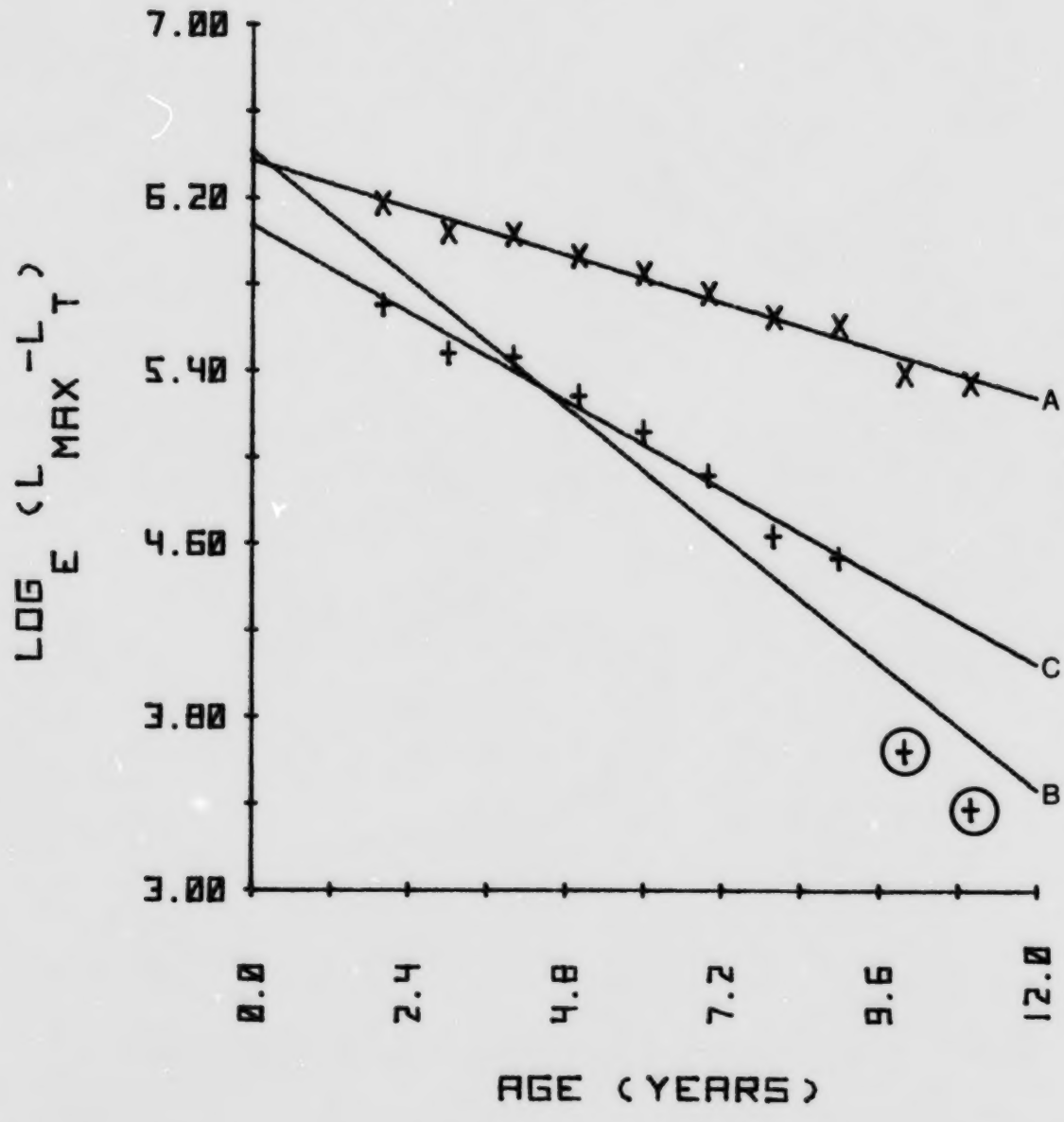

Fig. 14. Plots of $\log_e (L_\infty - l_t)$ versus t for Cedar Lake walleyes, 1981. Circled points on curve B were deleted to produce curve C (see Table 9).

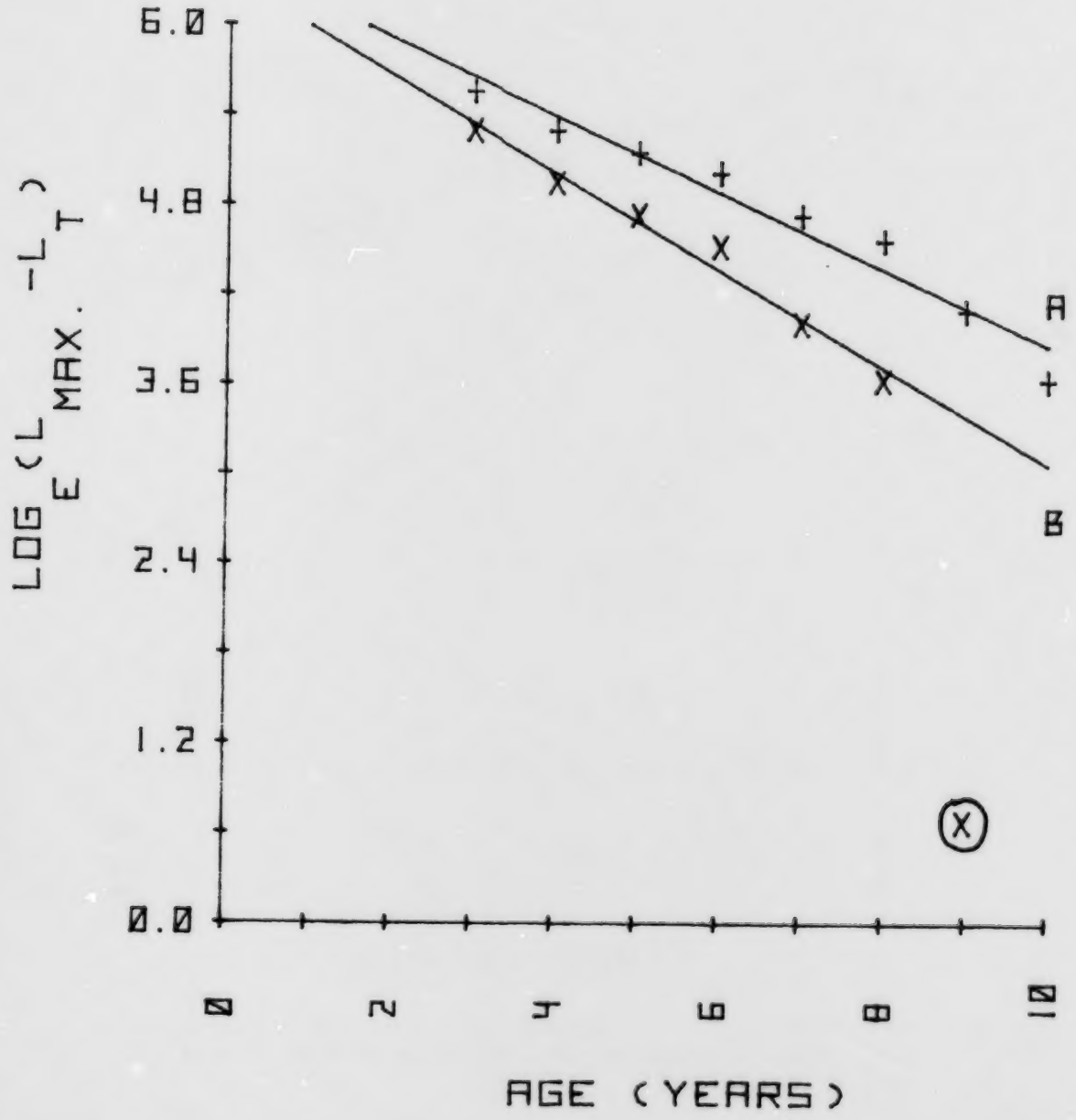

Fig. 15. Plots of $\log_e (L_\infty - l_t)$ versus t for Cedar Lake walleye, 1982. Curve A - L_∞ = 550.76, curve B - L_∞ = 491.78 and deleting last

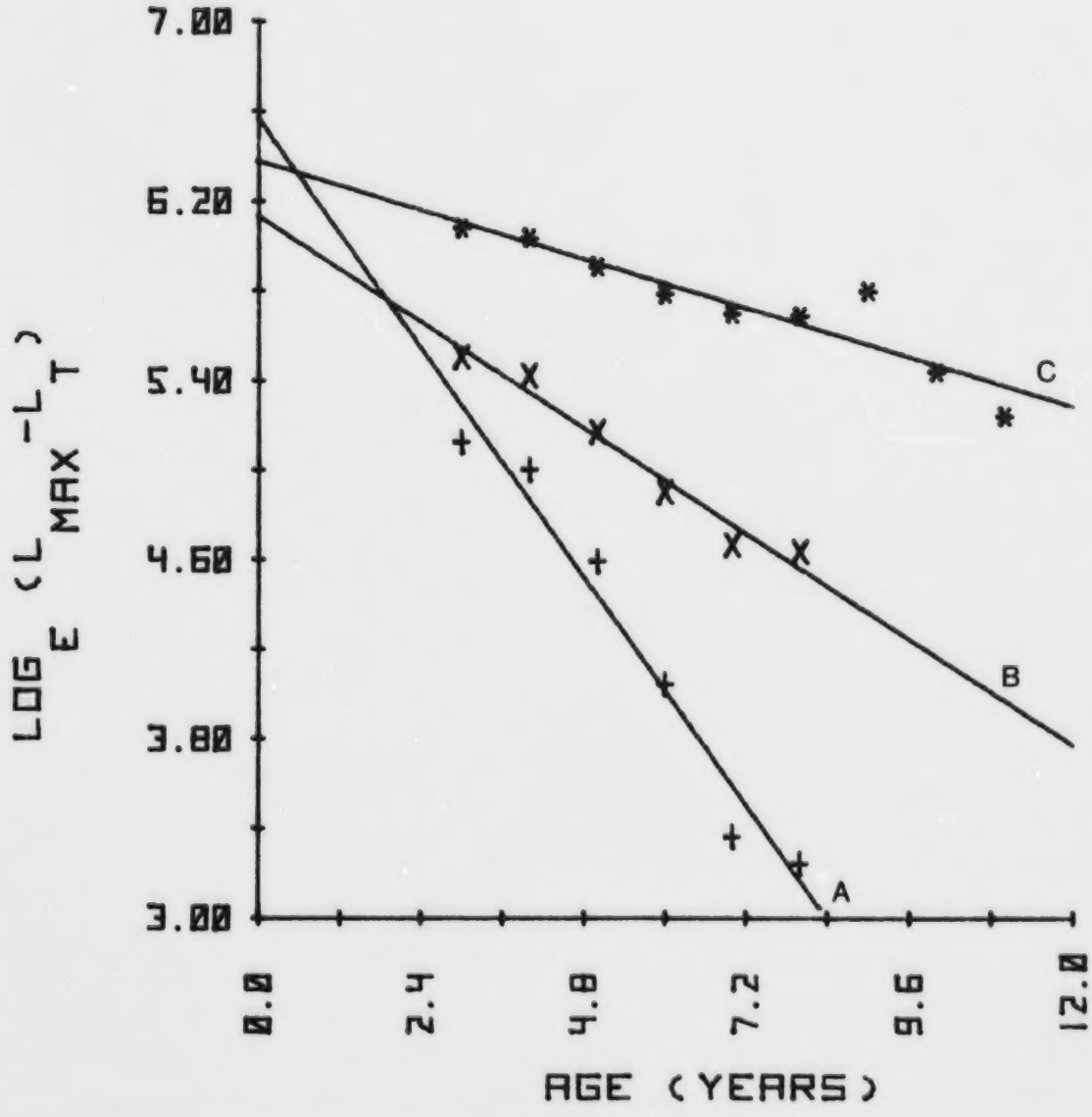

Fig. 16. Plots of $\log_e (L_\infty - l_t)$ versus t for Cedar Lake whitefish, 1981 (see Table 9).

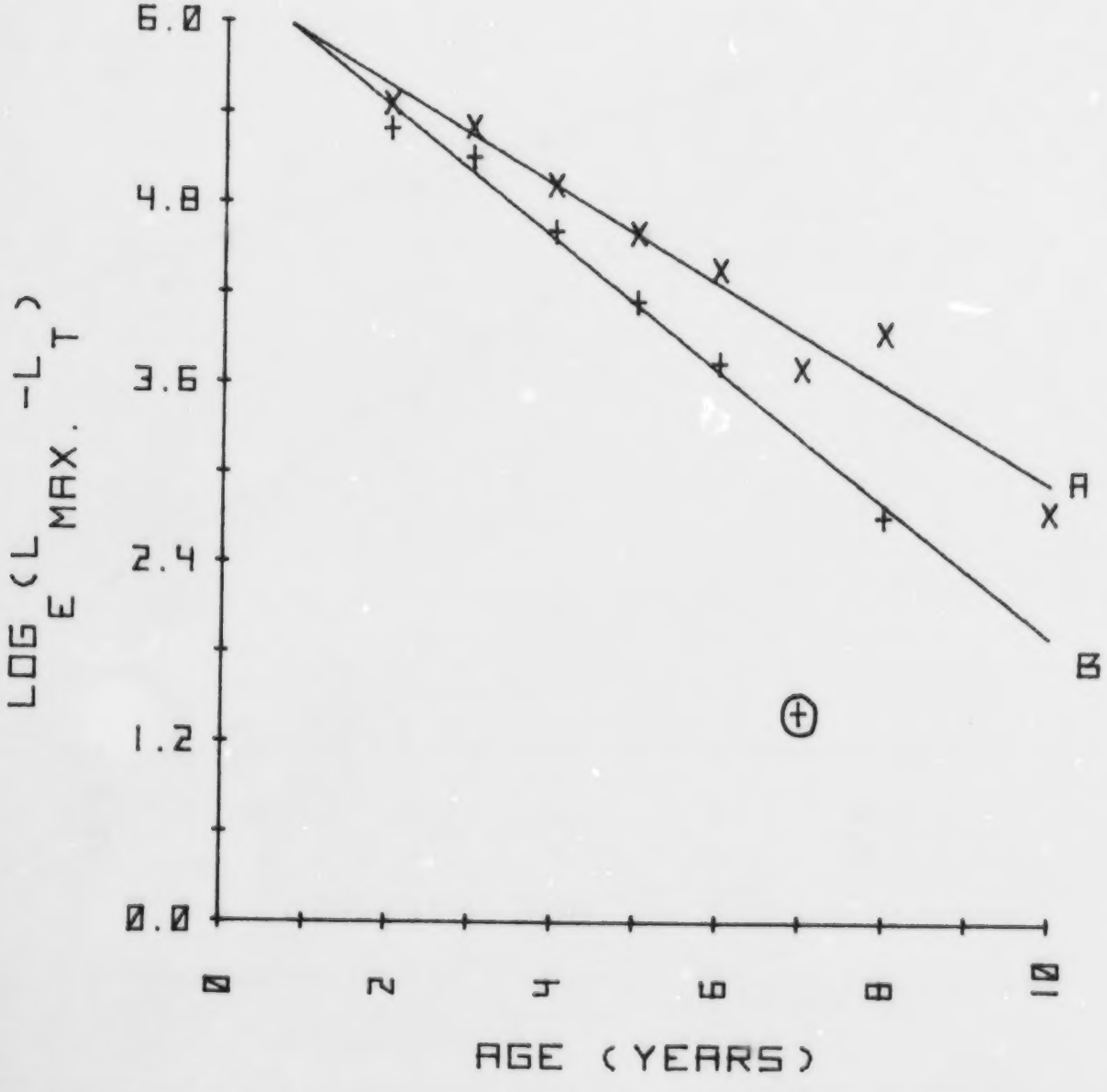

Fig. 17. Plots of $\log_e (L_\infty - l_t)$ versus t for Cedar Lake whitefish, 1982. Curve A - L_∞ = 523.7, curve B - L_∞ = 487.1 and deleting sixth point.

were used to derive parameters comprising the von Bertalanffy growth curves listed on Table 10 and plotted on Figs. 18 - 21. Walleye and whitefish exponential growth curves are listed on Table 10 and are plotted on Figs. 22 - 25.

Age compositions, catch curves and mortality rates from commercial and experimental samples

Age compositions, mean lengths and mean weights of commercially caught walleyes and whitefish are listed on Tables 11 and 12. Weighted mean ages of commercial catches were:

Year	whitefish	walleye
1981	4.11	7.21
1982	5.04	7.27

Experimental and commercial age compositions and catch curves of walleyes and whitefish sampled in 1981 and 1982 are plotted on Figs. 26 - 33. Robson-Chapman and regression estimates of mortality rates are listed on Table 13. Table 14 compares mean ages of commercial catches to mean ages of maturity interpolated from maturity ogives listed on Tables 3 and 4.

Mesh size effects

Numbers, body sizes, age distributions and maturity frequencies of walleyes and whitefish caught in the various meshes comprising the experimental gangs set in Cedar Lake from 1980 - 1982 are listed on Tables 15 - 20.

Table 10. Cedar Lake exponential and von Bertalanffy growth curves of walleyes and whitefish.

Species	Year	Growth curve		
		Exponential		von Bertalanffy
		$\log_e$ length = a + b · $\log_e$ age	Age range	$L_t = L_\infty (1 - e^{-k(t - t_o)})$
Walleye	1981	Y = 5.388 + .383X	2-11	A. $L_t = 770.92(1 - e^{-.091(t + 3.017)})$
				B. $L_t = 590.34(1 - e^{-.246(t + .139)})$
				C. $L_t = 590.34(1 - e^{-.169(t + 1.822)})$
	1982	Y = 5.208 + .446X	3-12	A. $L_t = 550.76(1 - e^{-.255(t + .425)})$
				B. $L_t = 491.78(1 - e^{-.323(t + .338)})$
Whitefish	1981	Y = 5.462 + .371X	3-11	A. $L_t = 797.78(1 - e^{-.091(t + 3.339)})$
				B. $L_t = 529.42(1 - e^{-.425(t - .695)})$
				C. $L_t = 606.86(1 - e^{-.197(t + 1.403)})$
	1982	Y = 5.446 + .349X	2-14	A. $L_t = 523.70(1 - e^{-.329(t + .08)})$
				B. $L_t = 487.09(1 - e^{-.440(t + .299)})$

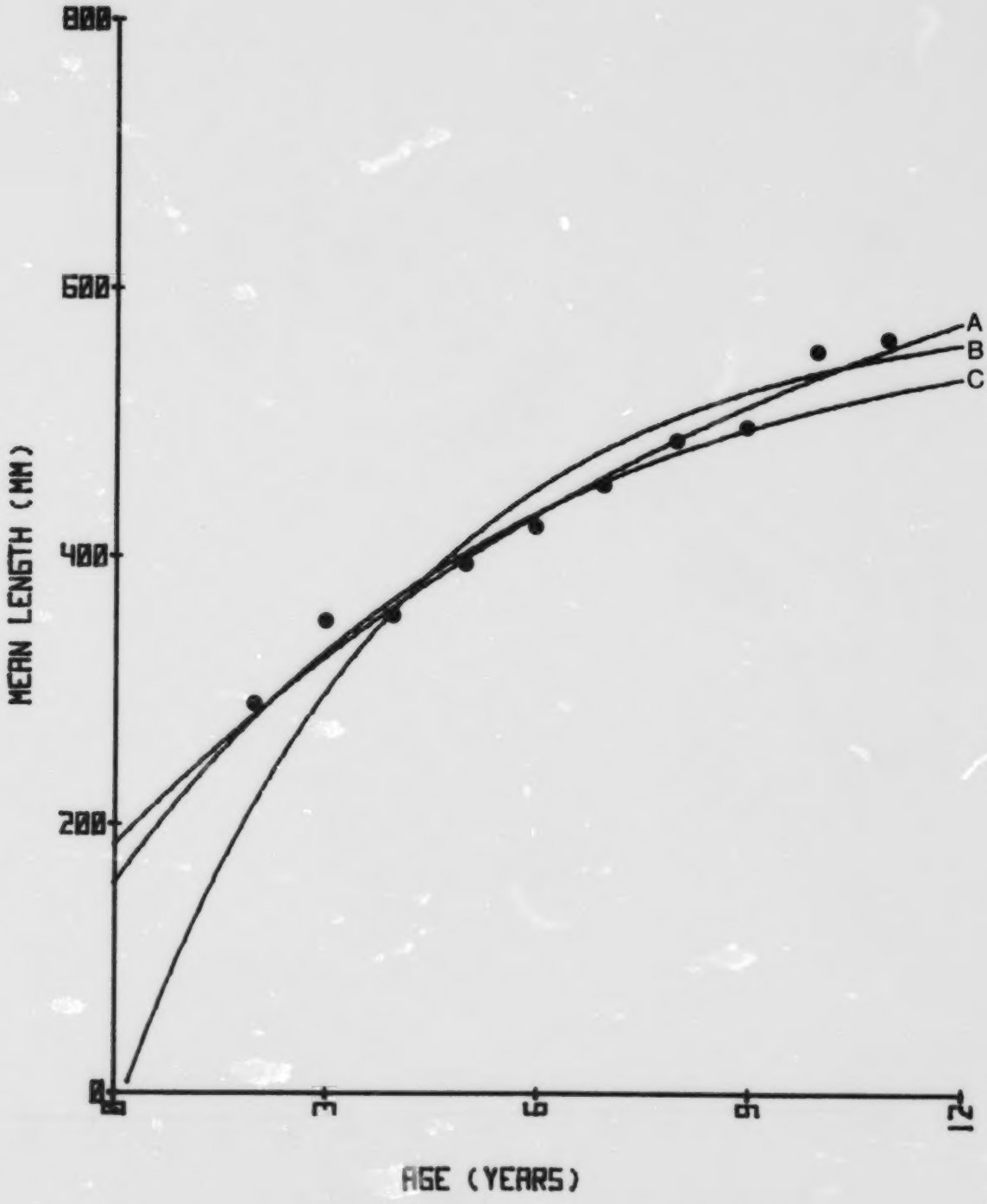

Fig. 18. Von Bertalanffy growth curves of Cedar Lake walleyes, 1981 (see Table 10).

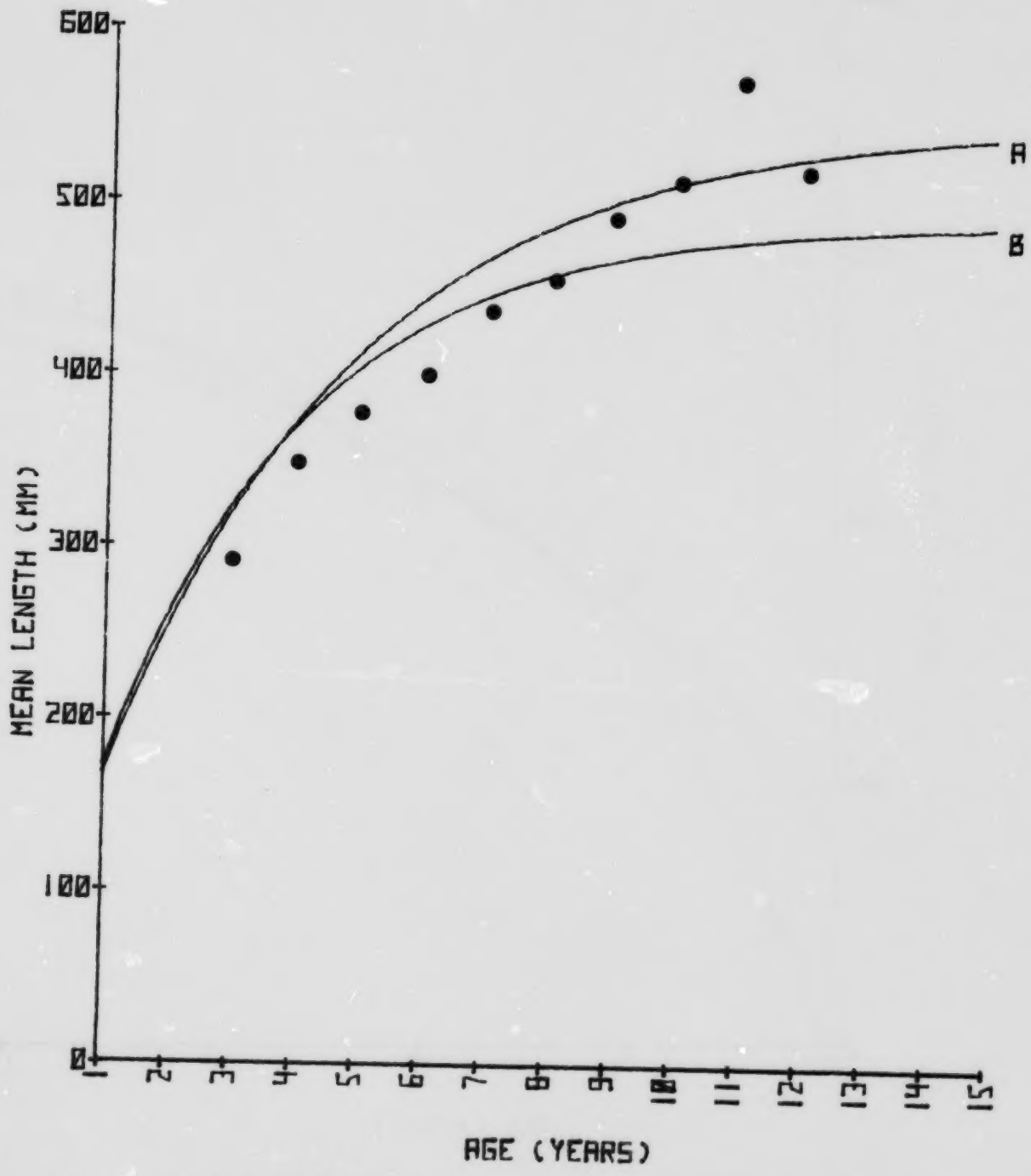

Fig. 19. Von Bertalanffy growth curves of Cedar Lake walleyes, 1982 (see Table 10).

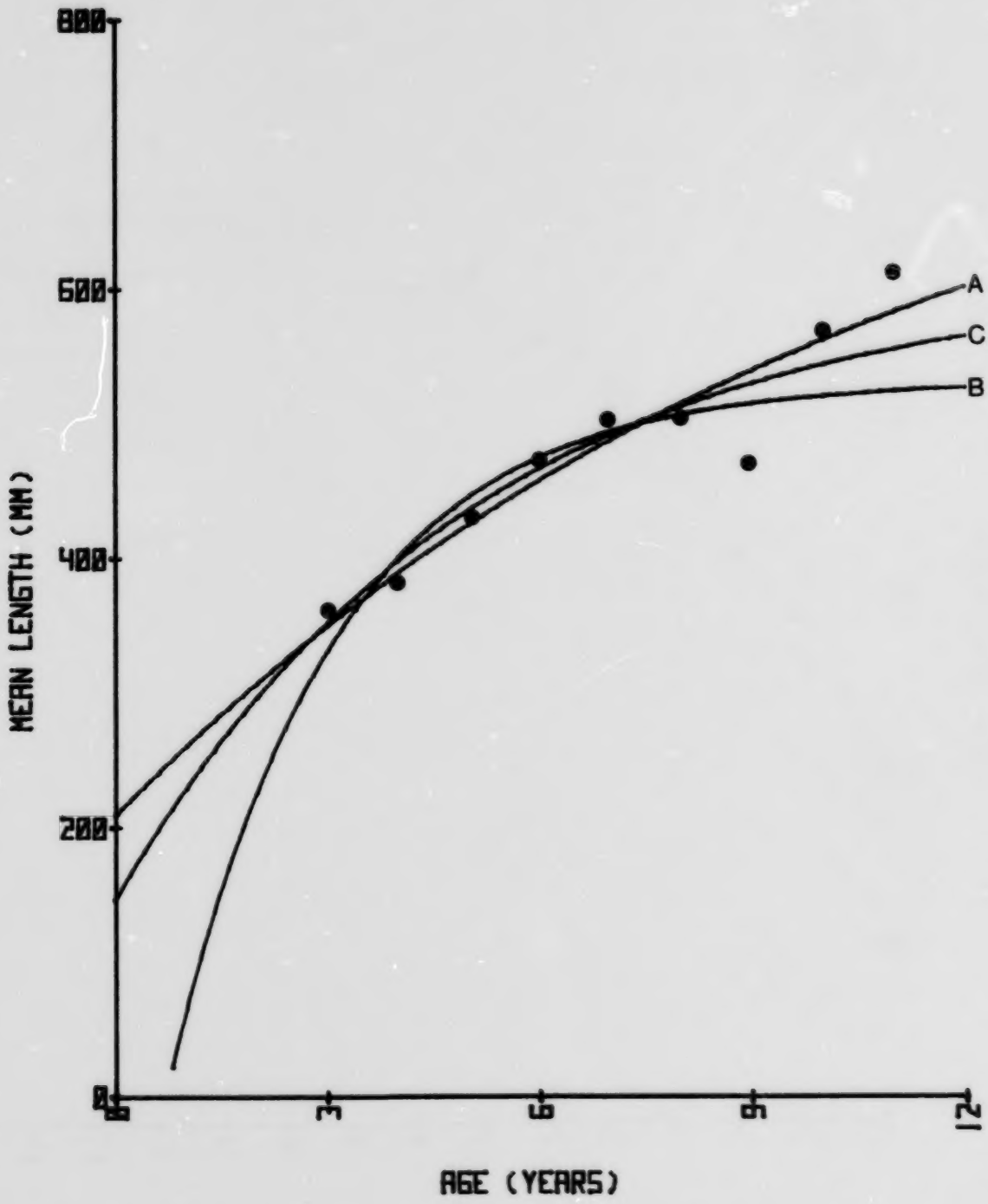

Fig. 20. Von Bertalanffy growth curves of Cedar Lake whitefish, 1981 (see Table 10).

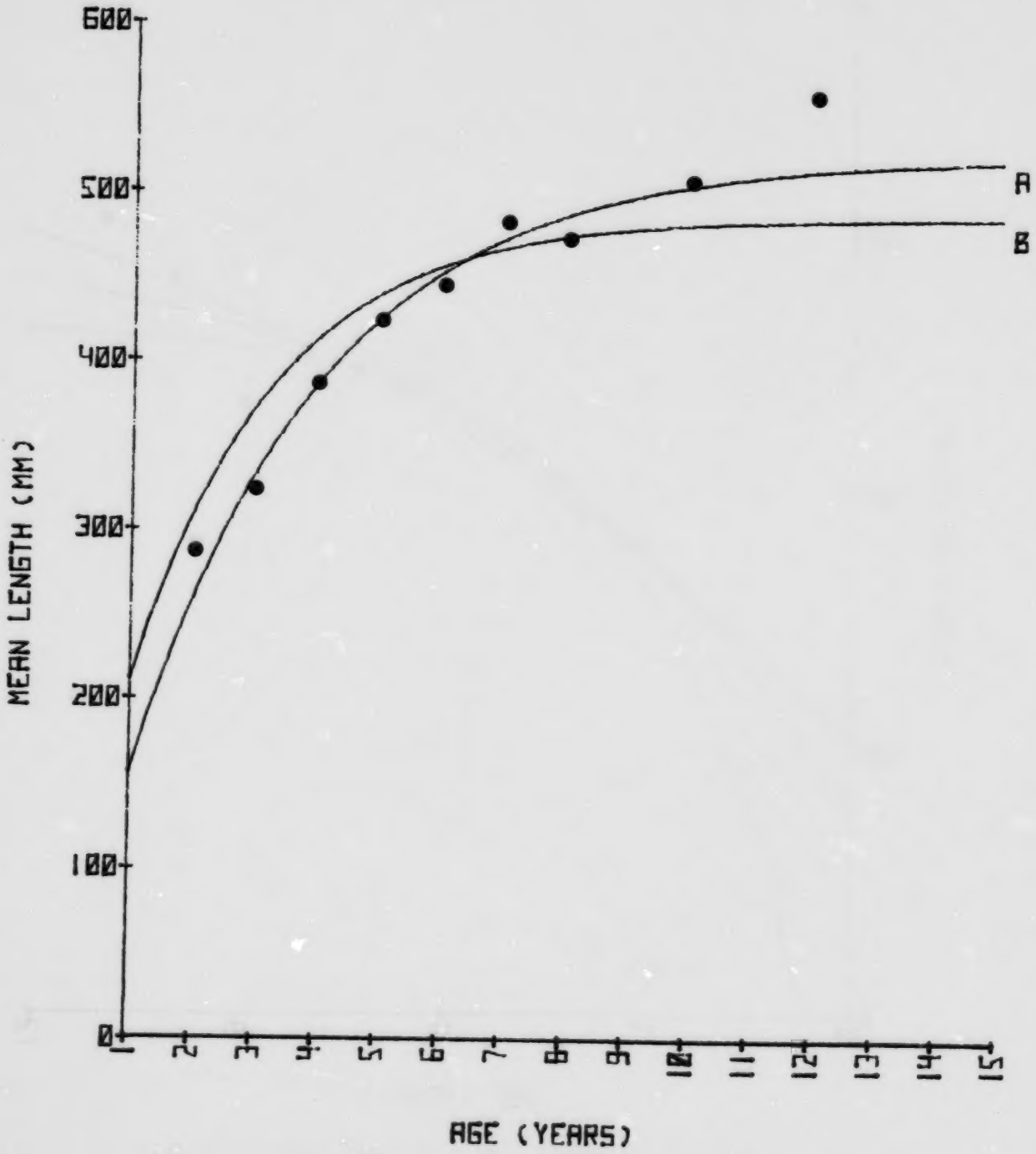

Fig. 21. Von Bertalanffy growth curves of Cedar Lake whitefish, 1982 (see Table 10).

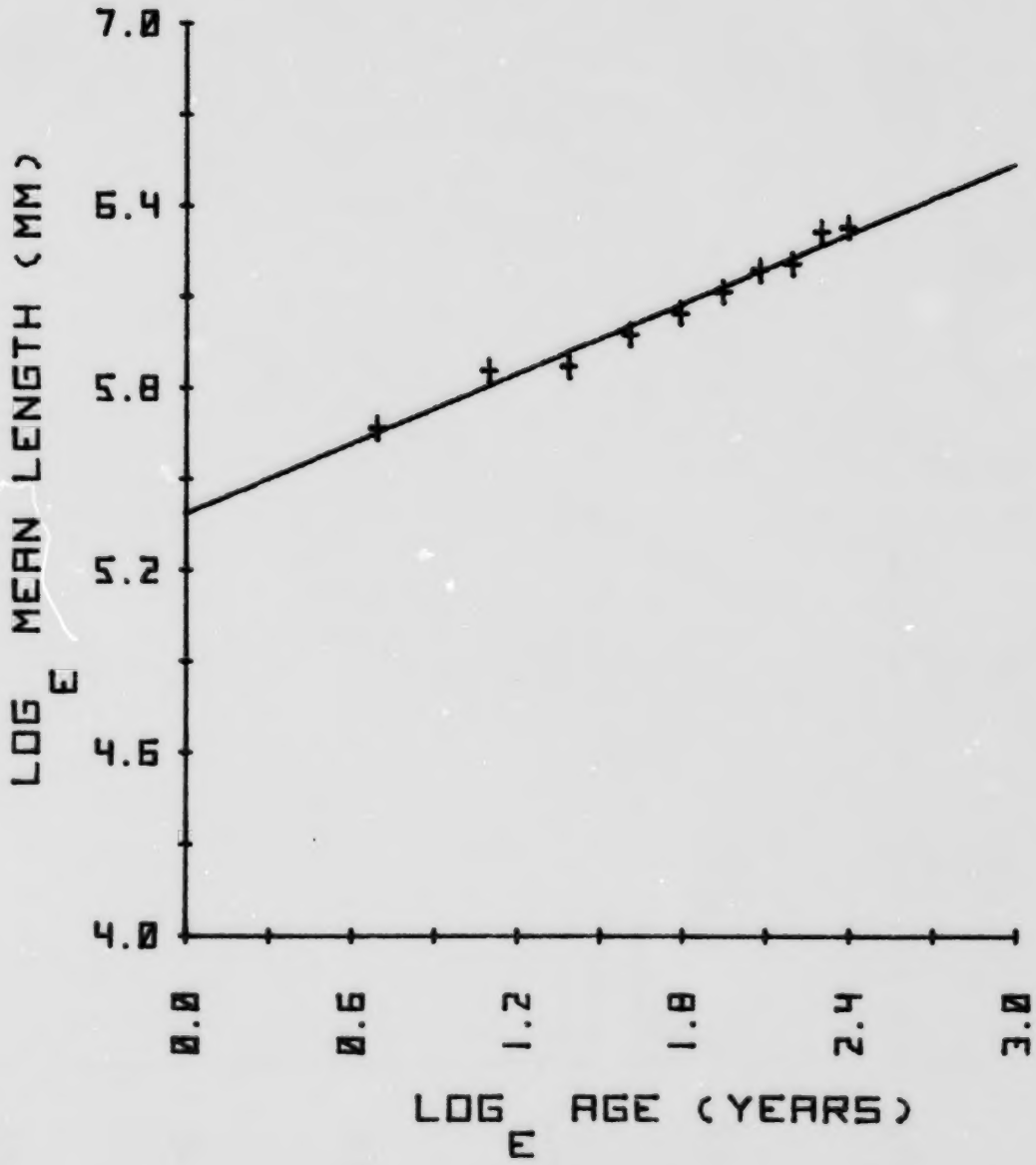

Fig. 22. Exponential growth curve of Cedar Lake walleyes, 1981 (see Table 10).

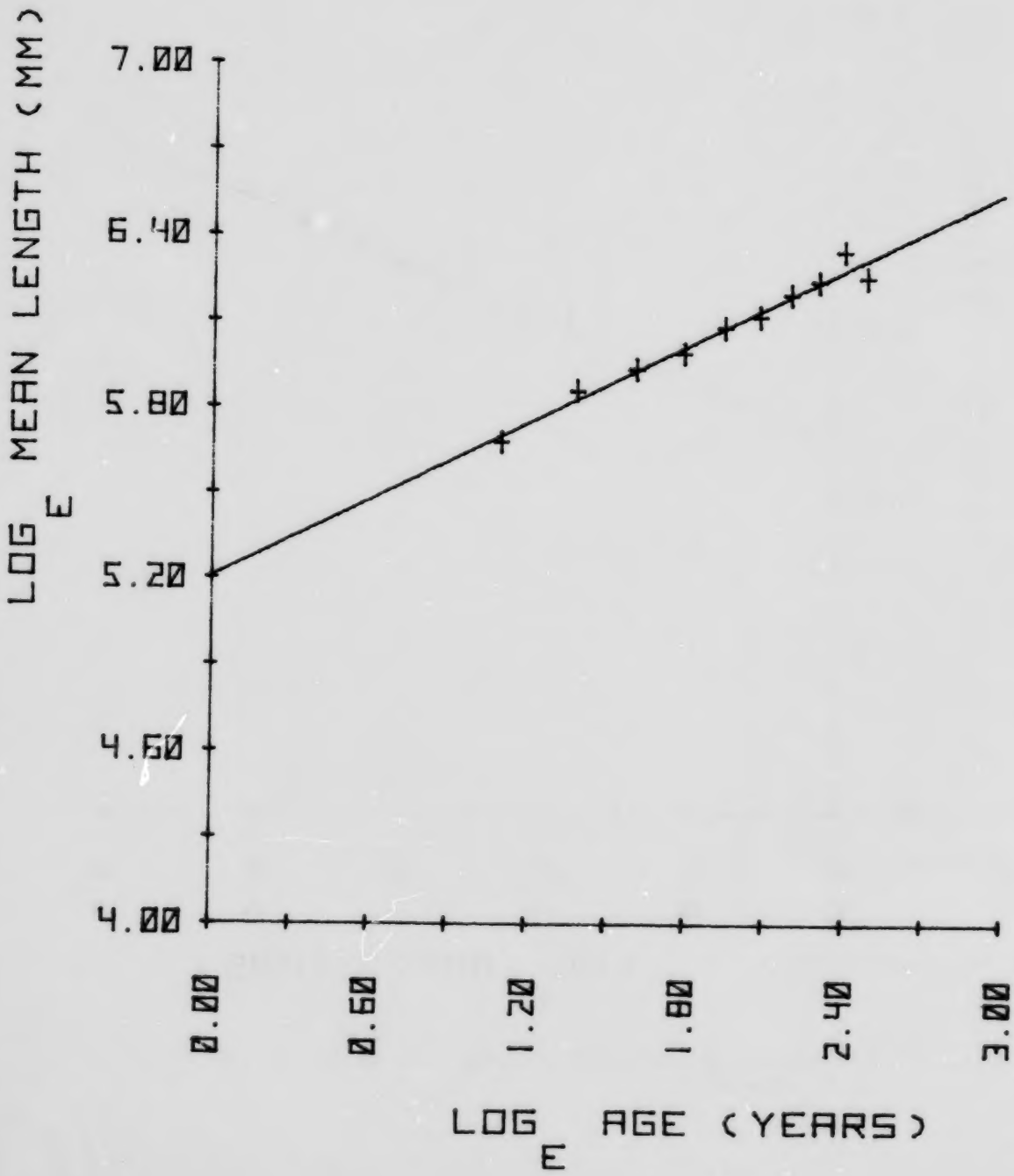

Fig. 23. Exponential growth curve of Cedar Lake walleyes, 1982 (see Table 10).

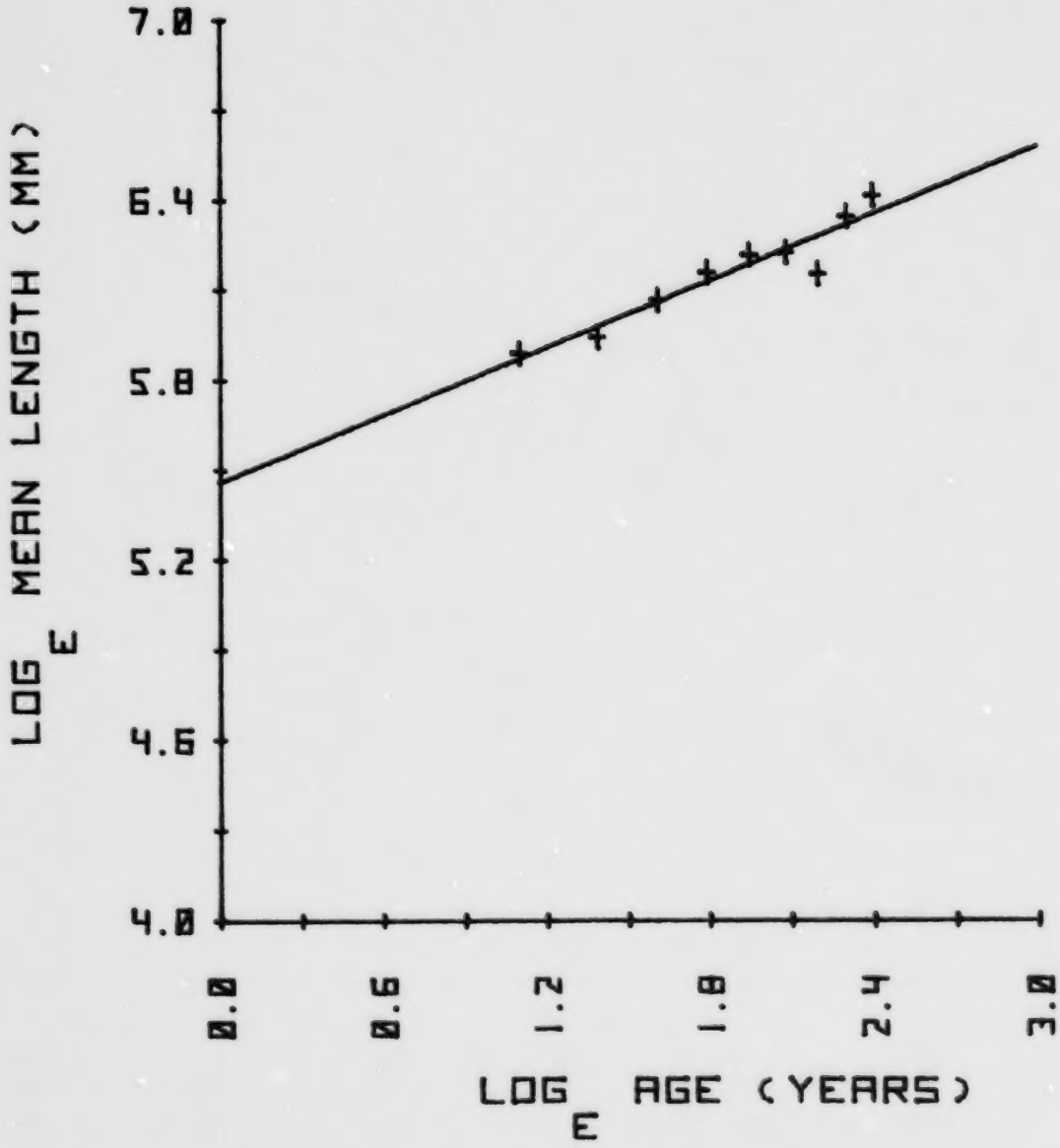

Fig. 24. Exponential growth curve of Cedar Lake whitefish, 1981 (see Table 10).

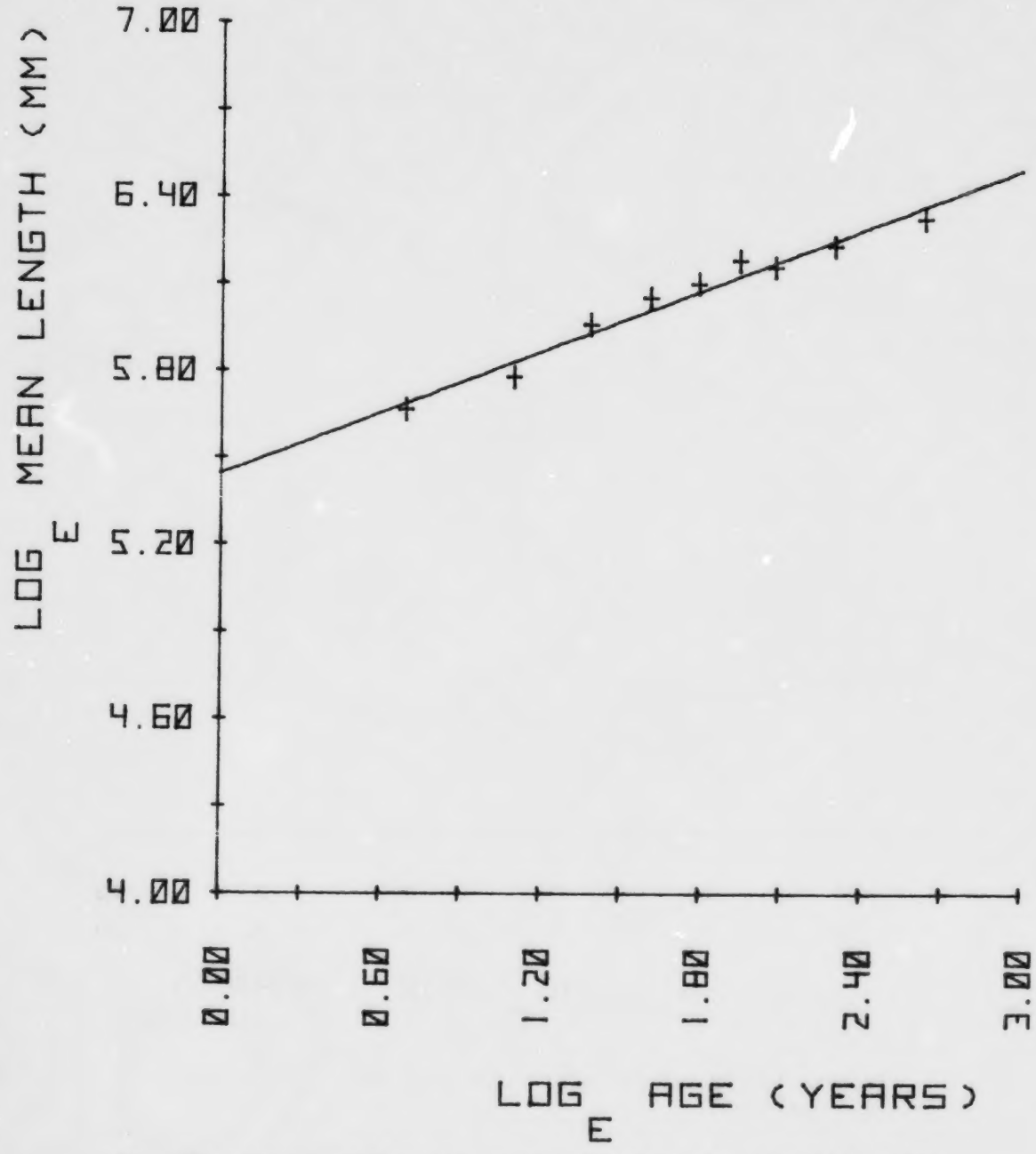

Fig. 25. Exponential growth curve of Cedar Lake whitefish, 1982 (see Table 10).

Table 11. Age-specific mean lengths and weights of commercially caught walleyes and whitefish from Cedar Lake, 1981.

Species	Age (years)	No. fish	Mean length (mm)	1 Standard deviation	Mean weight (gm)	1 Standard deviation
Walleye	5	7	390.24	28.96	777.14	183.82
	6	39	402.60	26.71	865.38	154.25
	7	114	418.23	26.95	946.93	164.46
	8	76	430.25	24.97	1001.32	159.72
	9	13	449.62	26.05	1080.00	195.62
	11	1	508.00	-	1480.00	-
Whitefish	3	36	358.44	15.79	774.17	107.37
	4	159	477.69	29.18	922.39	209.58
	5	48	423.44	39.20	1308.13	328.72
	6	6	477.33	29.81	1806.67	283.31
	7	1	535.00	-	2640.00	-

Table 12. Age-specifc mean lengths and weights of commercially caught walleyes and whitefish from Cedar Lake, 1982.

Species	Age (years)	No. fish	Mean length (mm)	1 Standard deviation	Mean weight (gm)	1 Standard deviation
Walleye	5	2	361.00	26.87	610.00	183.85
	6	31	405.87	20.41	856.13	122.57
	7	128	424.81	20.79	972.03	133.12
	8	80	442.60	22.48	1077.25	166.87
	9	6	444.67	44.72	1186.67	246.79
	10	2	516.00	5.66	1620.00	197.99
	11	1	506.00	-	1600.00	-
Whitefish	3	2	322.00	31.11	540.00*	169.71
	4	61	379.97	25.20	990.16	193.83
	5	118	417.59	24.11	1288.22	224.49
	6	62	422.32	20.50	1323.71	201.11
	7	7	475.14	18.58	1771.43	146.90

* dressed weight measured in 1982.

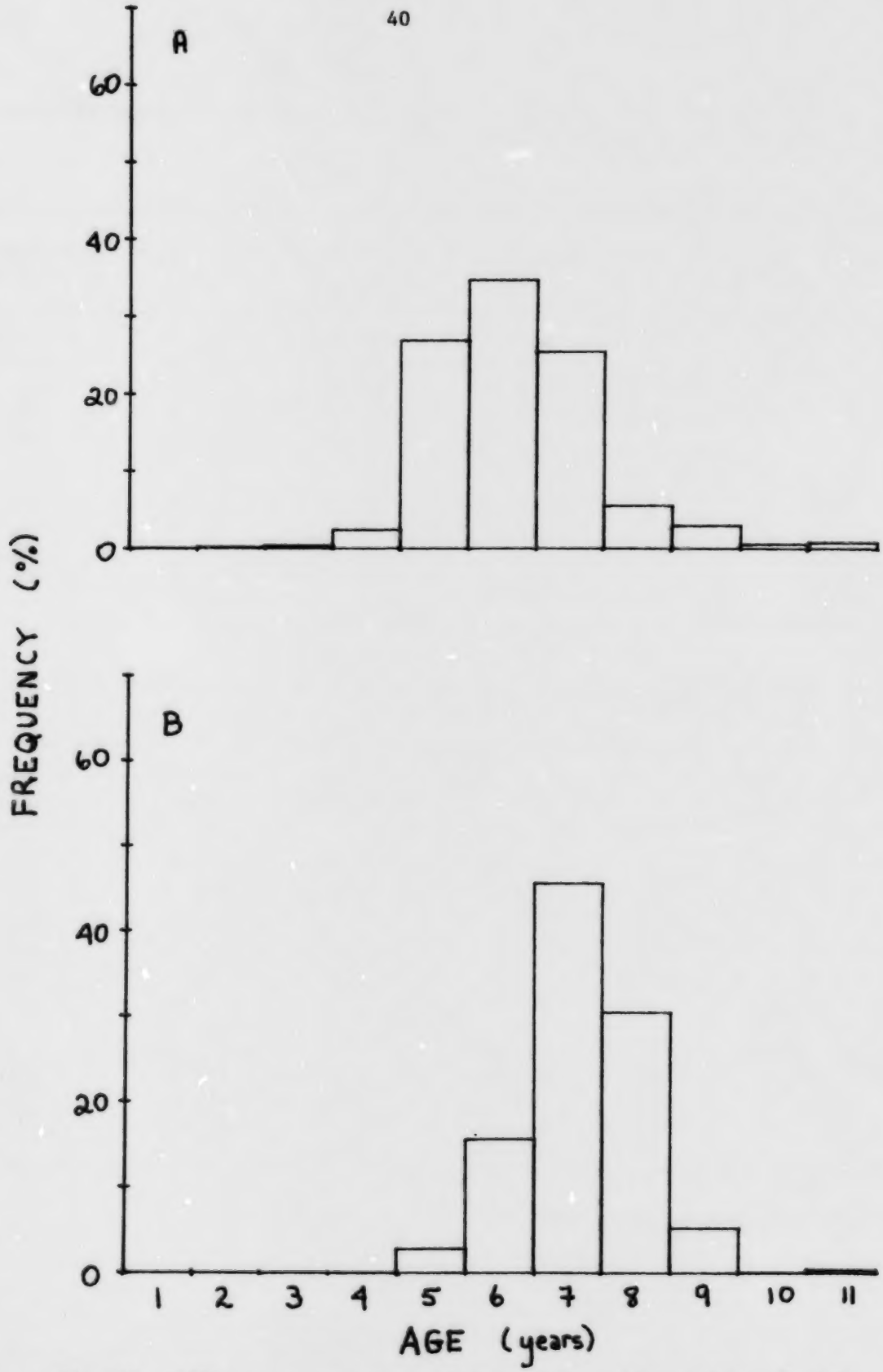

Fig. 26. 1981 age compositions of Cedar Lake walleyes determined from experimental nets (A) and commercial sampling (B).

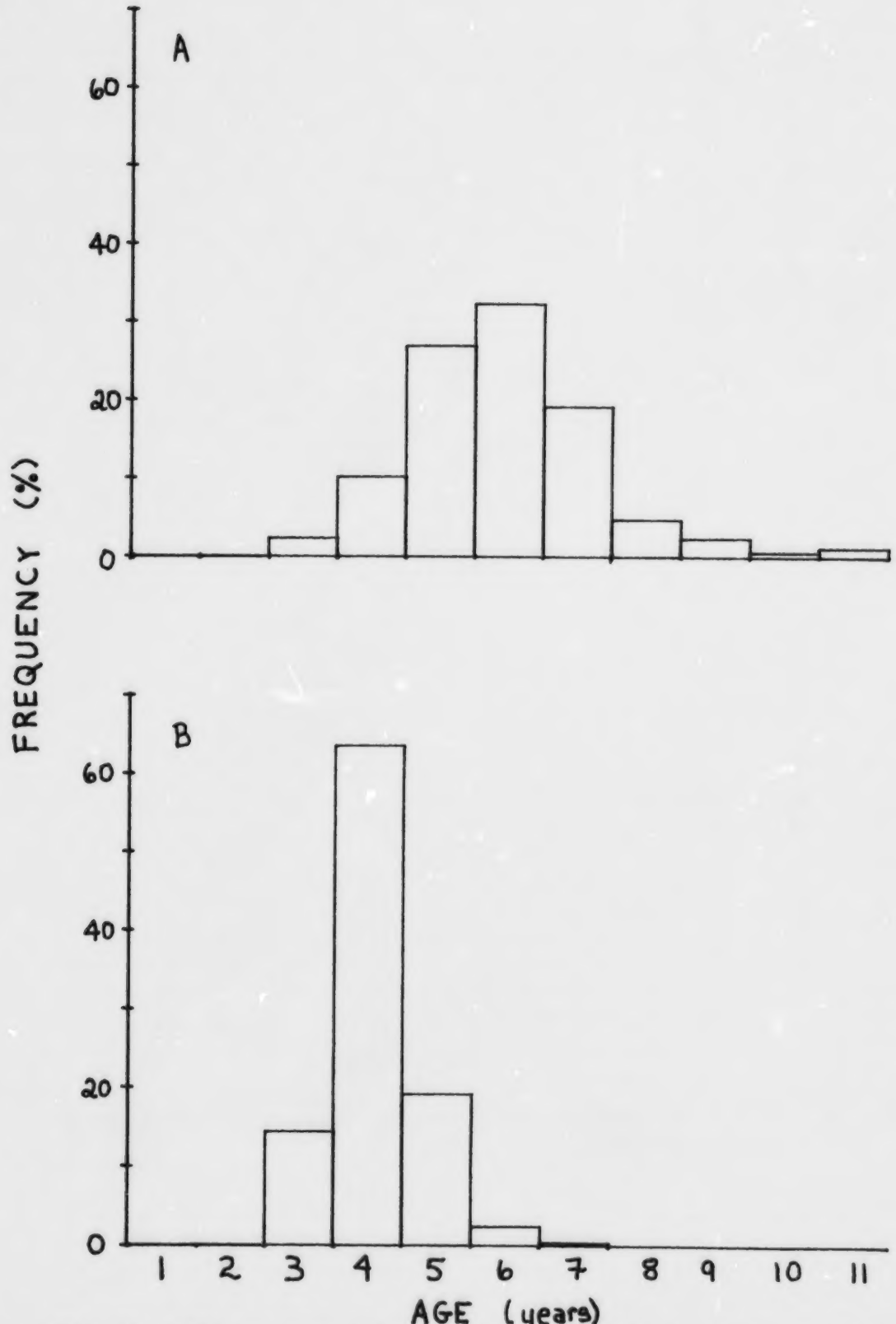

Fig. 27. 1981 age compositions of Cedar Lake whitefish determined from experimental nets (A) and commercial sampling (B).

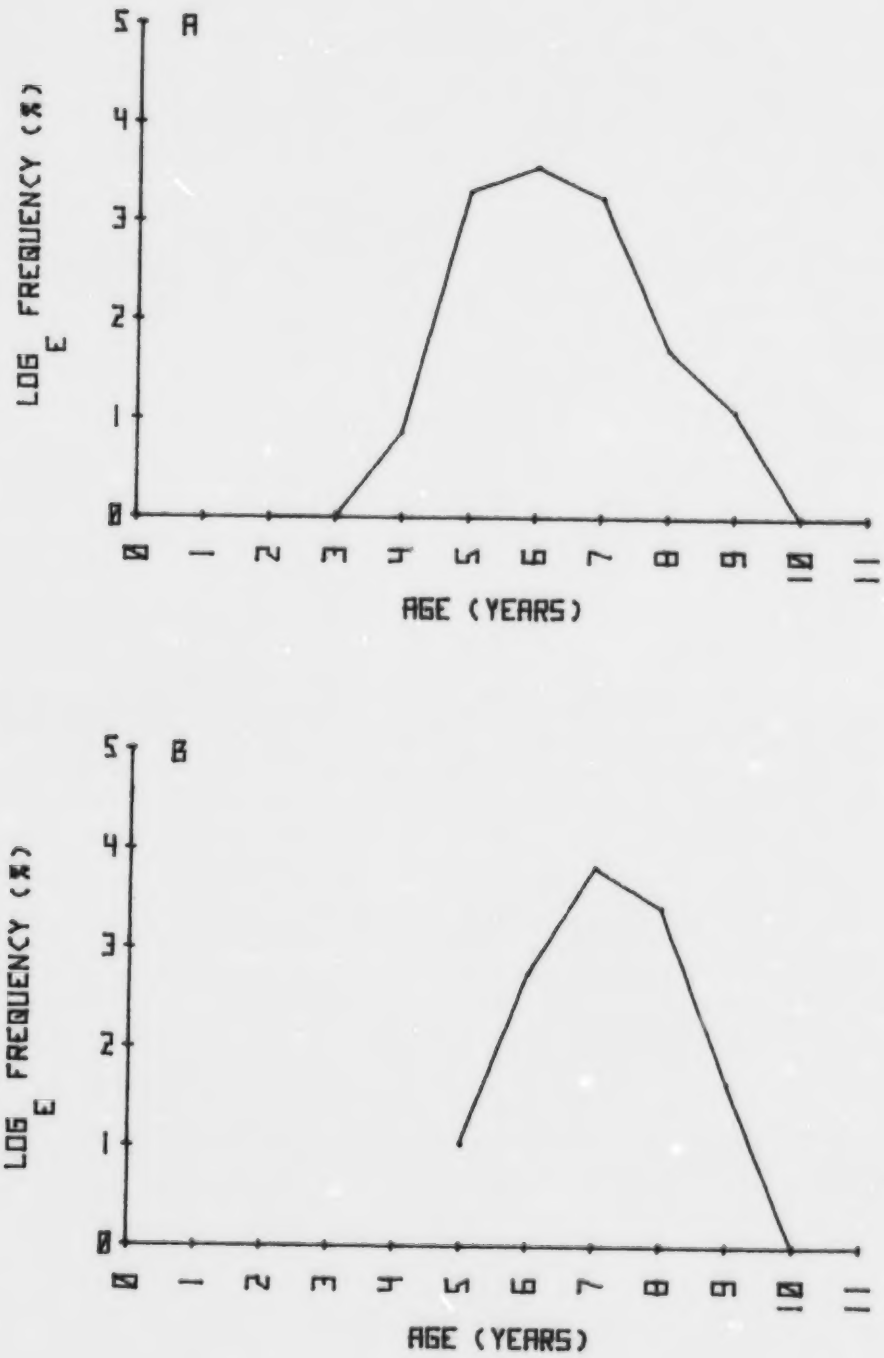

Fig. 28. 1981 catch curves of Cedar Lake walleyes: A - experimental, B - commercial.

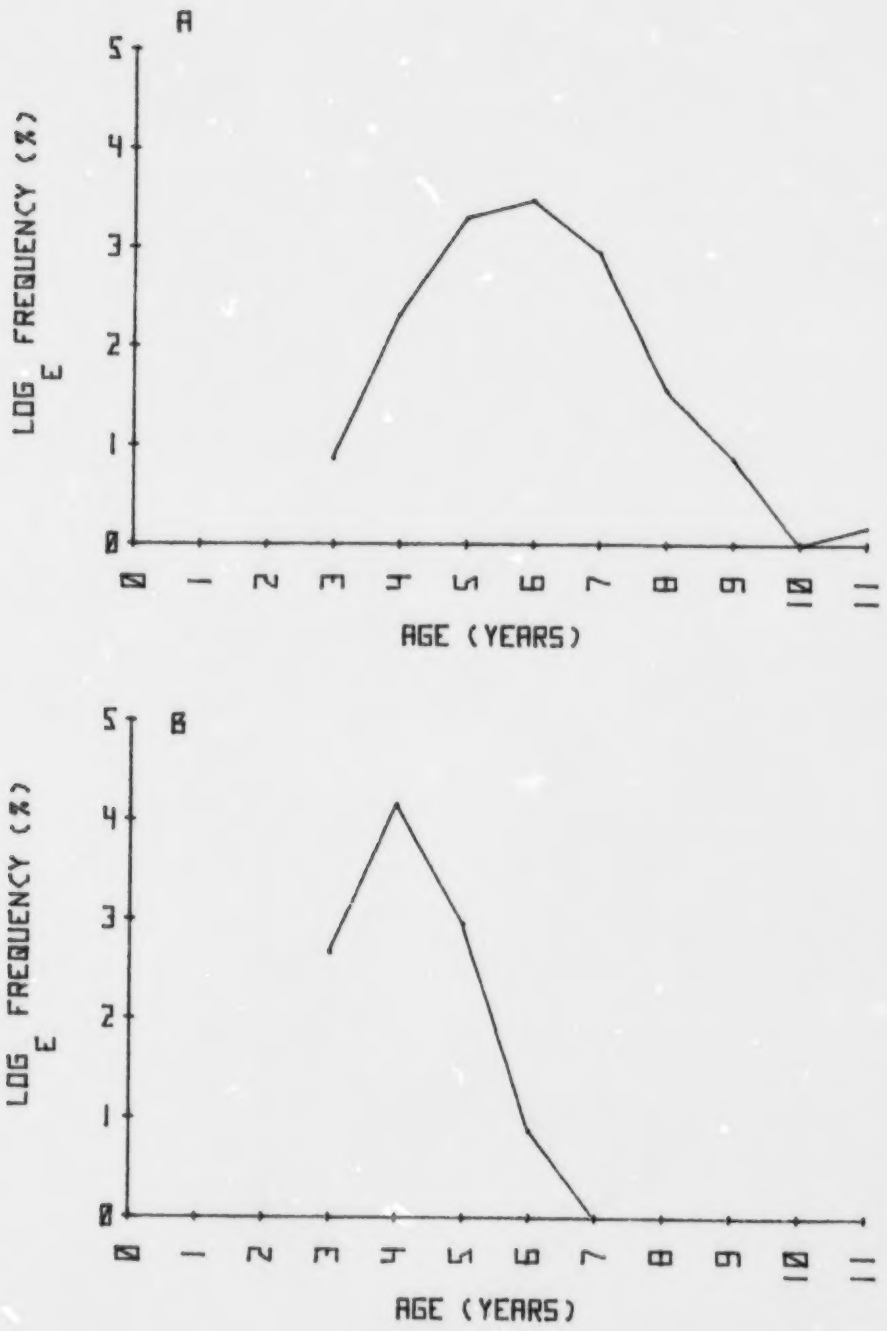

Fig. 29. 1981 catch curves of Cedar Lake whitefish: A - experimental, B - commercial.

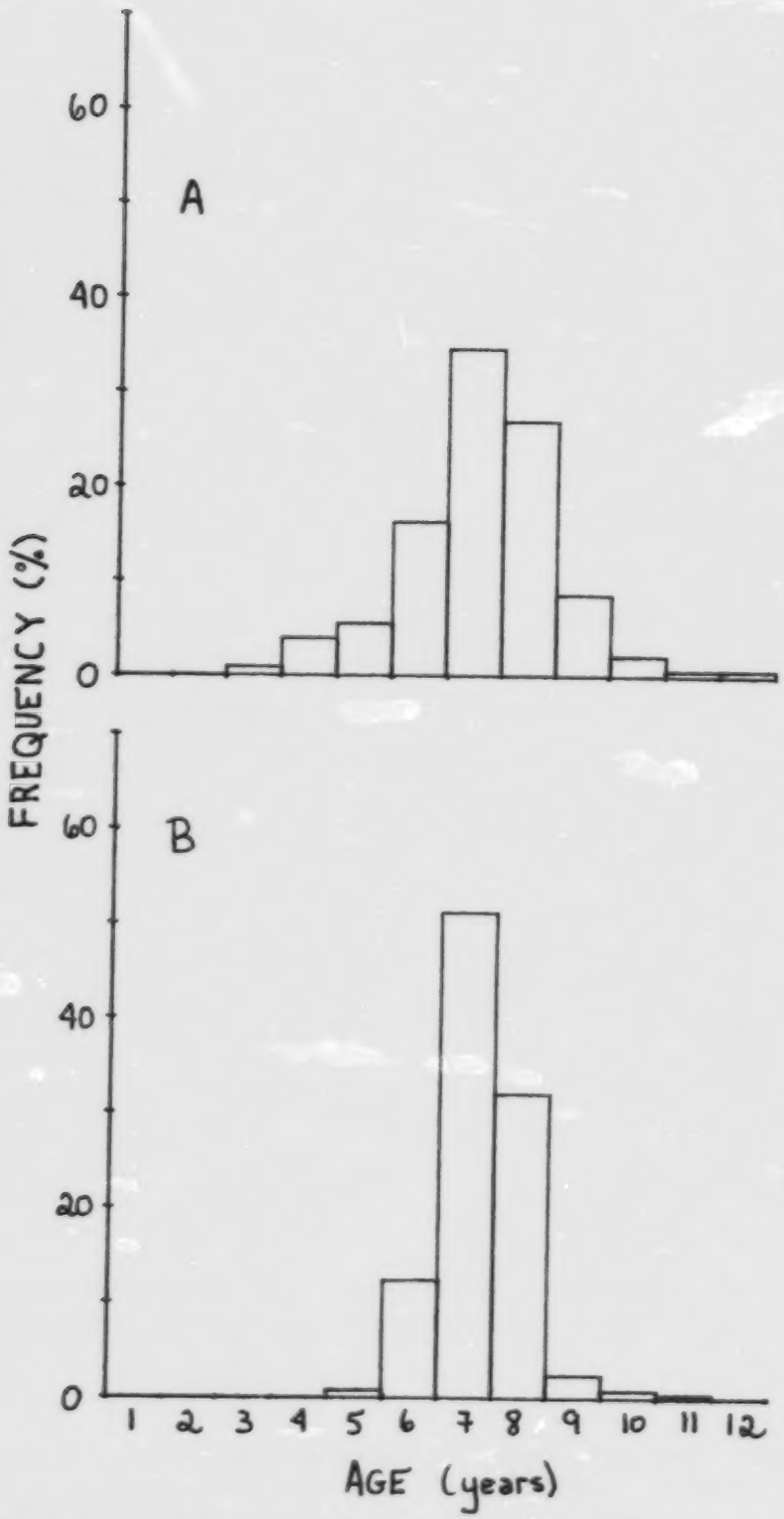

Fig. 30. 1982 age compositions of Cedar Lake walleyes. A - experimental, B - commercial.

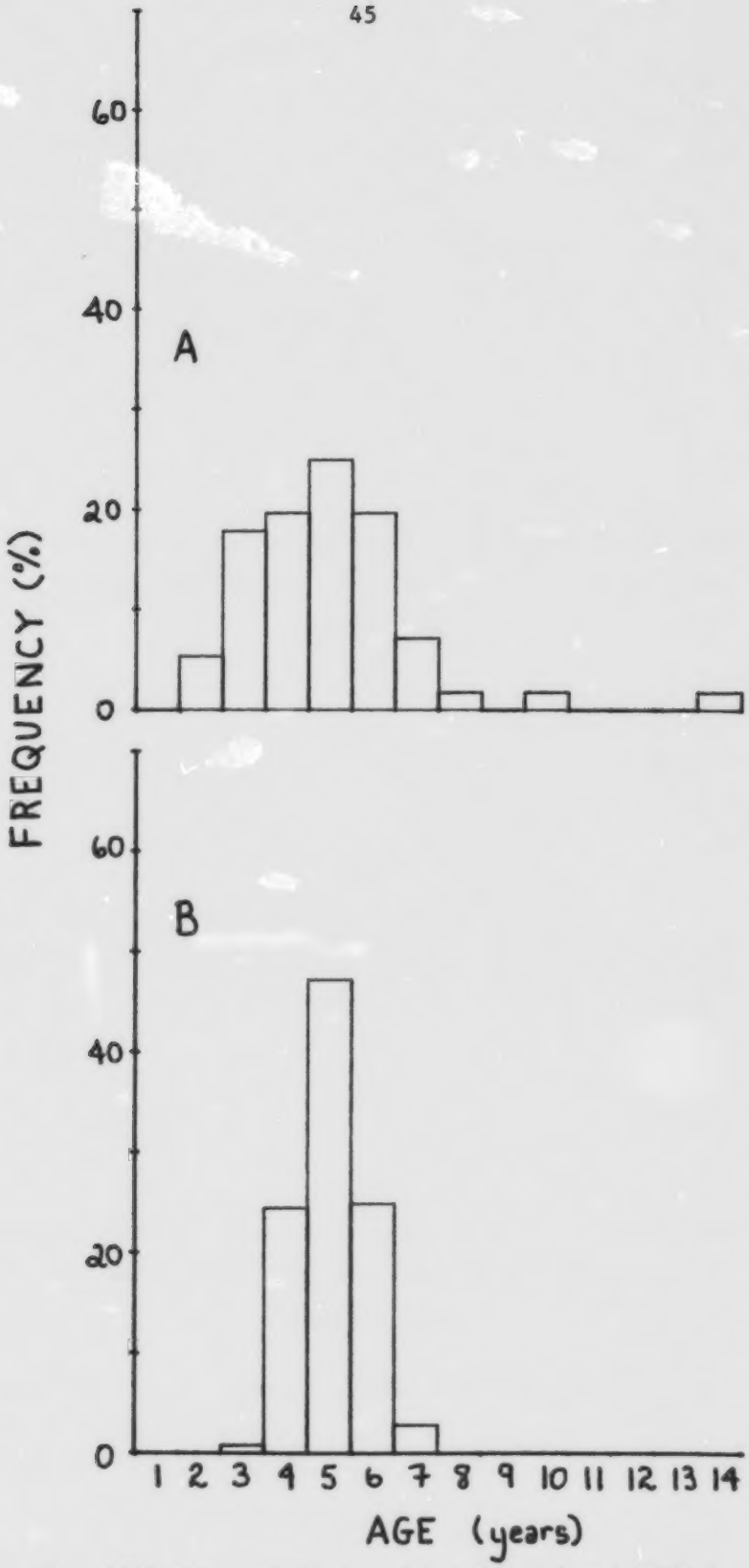

Fig. 31. 1982 age compositions of Cedar Lake whitefish. A - experimental, B - commercial.

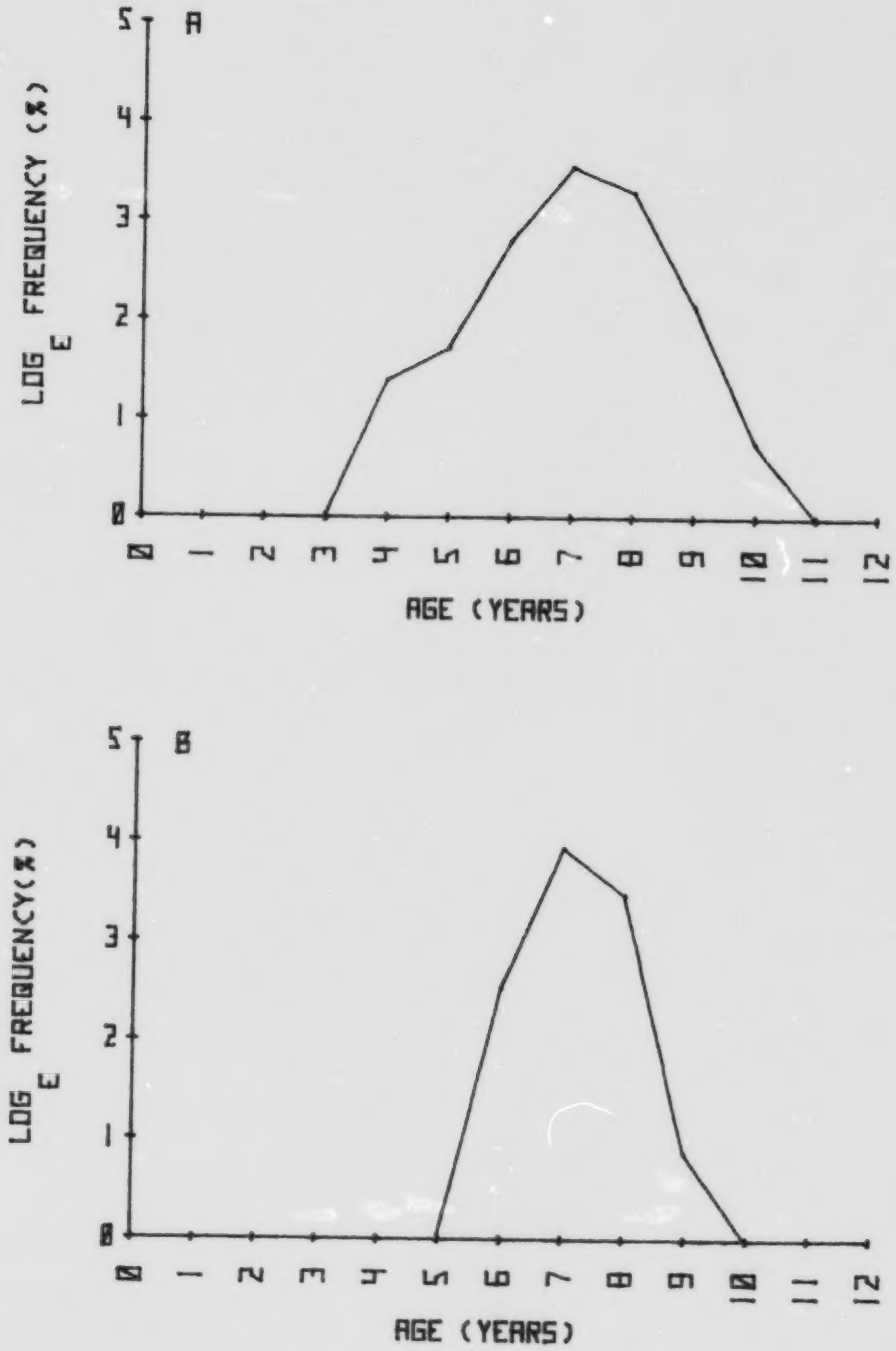

Fig. 32. 1982 catch curves of Cedar Lake walleyes. A - experimental, B - commercial.

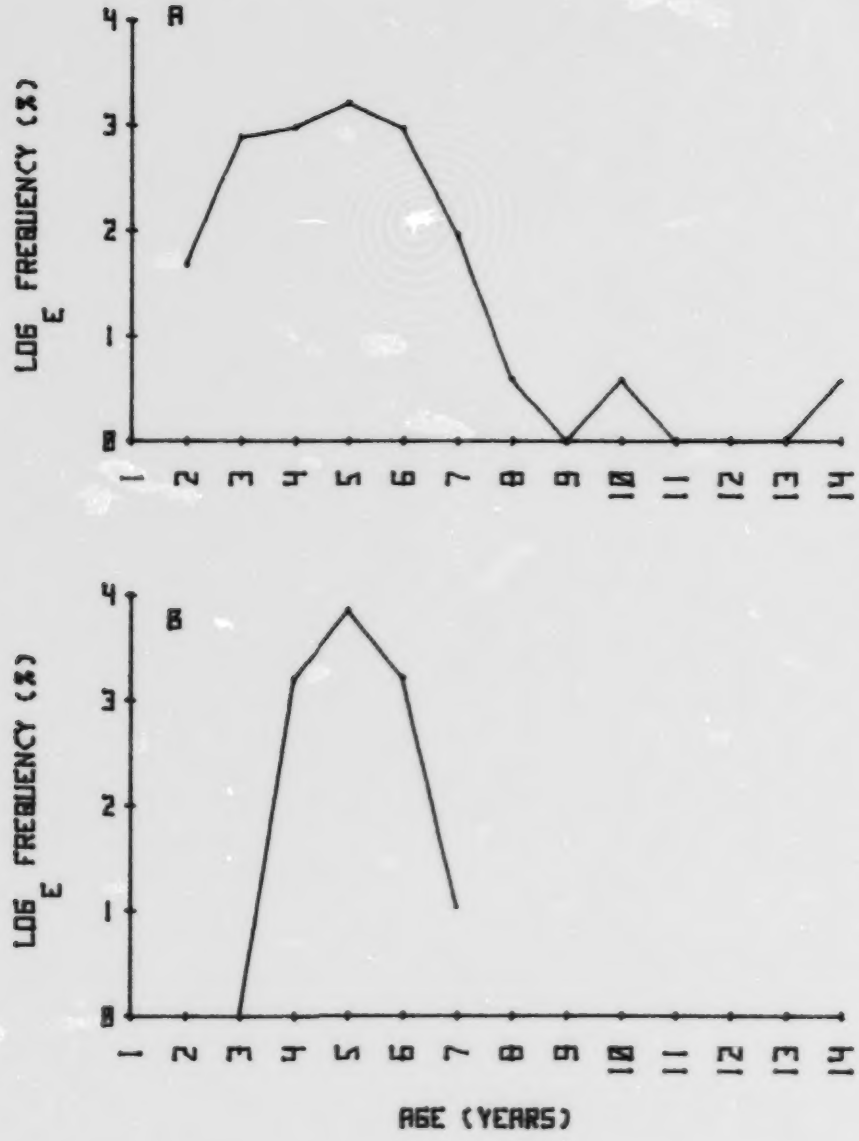

Fig. 33. 1982 catch curves of Cedar Lake whitefish. A - experimental, B - commercial.

Table 13. Mortality and survival rates of Cedar Lake walleye and whitefish stocks.

Species	Year	Robson-Chapman			Regression		
		Z	A	S ± 2 S.E.	Z	A	S
Walleye (experimental)	1981	1.152	.6841	.0532 < .3159 < .5786	.931	.6058	.3942
	1982	1.192	.6963	.0538 < .3037 < .5536	1.074	.6584	.3416
Walleye (commercial)	1981	1.936	.8558	-.0747 < .1442 < .3632	1.421	.7585	.2415
	1982	2.050	.8713	-.0811 < .1287 < .3385	1.424	.7593	.2407
Whitefish (experimental)	1981	.981	.6250	.0838 < .3750 < .6662	.762	.5333	.4667
	1982	1.251	.7139	-.0125 < .2861 < .5847	.595	.4484	.5516
Whitefish (commercial)	1981	2.048	.8710	-.1400 < .1290 < .3981	1.936	.8557	.1443
	1982	1.214	.7031	.1113 < .2969 < .4824	1.412	.7563	.2437

Table 14. Differences between mean ages of commercially caught fish and mean ages of maturity.

Species	Year	Sex	Age at 50% mature	Mean age of commercial catch	Abrosov's (1967) t index
Walleye	1981	male	4.32		
		female	5.78		+1.43
		combined	4.95	7.21	+2.26
	1982	male	4.34		
		female	7.01		+0.26
		combined	5.78	7.27	+1.49
Whitefish	1981	male	4.65		
		female	5.09		-0.98
		combined	4.80	4.11	-0.69
	1982	male	3.58		
		female	4.08		+0.96
		combined	3.80	5.04	+1.24

Table 15. 1980 Cedar Lake walleye mesh size effects.

Parameter	Mesh size (inches)				
	3.00	3.25	3.75	4.25	5.00
No. fish	78	99	60	9	9
No. immature	54	62	34	4	1
% immature	69.2	62.6	56.7	44.4	11.11
Mean length (mm)	388.91	387.76	425.32	447.78	481.56
Mean weight (gm)	708.33	694.24	908.00	1025.56	1392.22
Age (years)	Frequency (%)				
5	10.26	6.06			11.11
6	29.49	25.25	13.33		
7	23.08	27.27	30.00	11.11	
8	26.92	34.34	40.00	33.33	11.11
9	3.85	4.04	10.00	44.44	33.33
10	3.85	3.03	3.33	11.11	11.11
11					22.22
12	1.28		3.33		
13	1.28				
14					
15					11.11
Mean age (years)	6.54	7.14	7.73	8.55	9.67
Mean biomass mesh^{-1} (kg)	9.21	11.46	9.08	1.54	2.09
Mean no. fish mesh^{-1}	13	16.5	10	1.5	1.5

Table 16. 1981 Cedar Lake walleye mesh size effects.

Parameter	Mesh size (inches)				
	3	3.25	3.75	4.25	5.00
No. fish	74	99	149	105	79
No. immature	27	29	40	26	10
% immature	36.5	29.29	26.85	24.76	12.66
Mean length (mm)	409.00	405.70	423.05	436.17	474.20
Mean weight (gm)	838.65	821.41	936.04	1060.76	1445.32
Age (years)	Frequency (%)				
2		1.01			
3		2.02			
4	2.70	6.06	2.68		
5	43.24	33.33	33.56	15.24	6.33
6	31.08	34.34	36.24	50.48	15.19
7	18.92	19.19	19.46	27.62	48.10
8	2.70	2.02	4.70	4.76	15.19
9	1.35		2.01	1.90	11.39
10		2.02	0.67		
11			0.67		3.80
Mean age (years	5.8	5.8	6.0	6.28	7.25
Mean biomass mesh^{-1} (kg)	10.34	13.55	23.25	18.56	19.03
Mean no. fish mesh^{-1}	12.33	16.5	24.83	17.5	13.17

Table 17. 1982 Cedar Lake walleye mesh size effects.

Parameter	Mesh size (inches)				
	3.00	3.25	3.75	4.25	5.00
No. fish	81	49	87	74	36
No. immature	30	23	31	17	3
% immature	37.0	46.9	35.6	23.0	8.3
Mean length (mm)	420.12	419.10	421.93	453.65	476.78
Mean weight (gm)	923.21	934.69	916.09	1168.11	1405.56
Age (years)	Frequency (%)				
3	2.47				2.78
4	2.47	12.24	5.75		
5	8.64	16.33	3.45		
6	24.69	14.29	18.39	12.16	2.78
7	37.04	34.69	40.23	29.73	25.00
8	19.75	14.29	28.74	35.14	38.89
9	4.94	4.08	2.30	16.22	22.22
10		2.04	1.15	4.05	5.56
11		2.04			2.78
12				2.70	
Mean age (years)	6.70	6.53	6.94	7.81	7.97
Mean biomass mesh^{-1} (kg)	9.35	5.73	9.96	10.81	6.33
Mean no. fish mesh^{-1}	10.1	6.13	10.9	9.3	4.5

Table 18. 1980 Cedar Lake whitefish mesh size effects.

Parameter	Mesh size (inches)				
	3.00	3.25	3.75	4.25	5.00
No. fish	30	23	43	45	93
No. immature	17	11	19	16	12
% immature	56.7	47.8	44.2	35.6	12.9
Mean length (mm)	371.77	387.74	414.84	423.78	443.51
Mean weight (gm)	954.03	1150.00	1463.95	1523.11	1688.60
Age (years)	Frequency (%)				
1	6.67				
2	10.00				
3	10.00			2.22	
4	33.33	30.43	30.23	15.56	5.38
5	20.00	43.48	30.23	31.11	38.71
6	13.33	17.39	25.58	26.67	25.81
7	3.33	4.35	6.98	8.89	15.05
8			2.33	13.33	13.98
9		4.35	2.33		1.08
10	3.33			2.22	
11					
12					
13			2.33		
Mean age (years)	4.27	5.13	5.44	5.76	5.97
Mean biomass mesh^{-1} (kg)	4.77	4.41	10.49	11.42	26.17
Mean no. fish mesh^{-1}	5	3.8	7.2	7.5	15.5

Table 19. 1981 Cedar Lake whitefish mesh size effects.

Parameter	Mesh size (inches)				
	3	3.25	3.75	4.25	5
No. fish	15	30	40	29	53
No. immature	5	8	6	6	8
% immature	33.33	26.67	15.00	20.69	15.09
Mean length (mm)	427.20	456.53	453.80	456.21	472.00
Mean weight (gm)	1500.00	1799.33	1741.25	1829.66	2020.38
Age (years)	Frequency (%)				
3	13.33	3.33	2.50		
4	6.67	20.00	5.00	10.34	9.43
5	40.00	10.00	42.50	17.24	26.42
6	26.67	36.67	30.00	37.93	30.19
7	6.67	16.67	15.00	20.69	26.42
8	6.67	10.00		13.79	
9			5.00		3.77
10					1.89
11		3.33			1.89
Mean age	5.27	5.93	5.70	6.1	6.1
Mean biomass mesh^{-1} (kg)	3.75	8.99	11.61	8.84	17.85
Mean no. fish mesh^{-1}	2.5	5.0	6.6	4.8	8.8

Table 20. 1982 Cedar Lake whitefish mesh size effects.

Parameter	Mesh size (inches)				
	3.00	3.25	3.75	4.25	5.00
No. fish	12	6	16	6	16
No. immature	8	1	6	2	1
% immature	66.7	16.67	37.5	33.3	6.25
Mean length (mm)	360.00	427.33	398.50	408.00	434.13
Mean weight (gm)	1000.00	1636.67	1206.25	1423.33	1587.50
Age (years)	Frequency (%)				
2	16.67	16.67			
3	33.33	16.67	18.75	16.67	6.25
4	8.33		37.50	33.33	12.50
5	16.67	33.33	12.50	33.33	37.50
6	16.67		18.75		37.50
7		16.67	12.50		6.25
8				16.67	
9					
10		16.67			
11					
12					
13					
14	8.33				
Mean age (years)	4.67	5.33	4.69	4.83	5.25
Mean biomass $mesh^{-1}$ (kg)	1.5	1.23	2.41	1.07	3.18
Mean no. fish $mesh^{-1}$	1.5	0.75	2.0	0.75	2.0

Changes in walleye and whitefish cohorts and vital parameters from 1979 - 1982.

Changes in age frequency distributions and age-specific mean lengths of walleyes and whitefish determined from experimental and commercial samples from 1979 - 1982 are listed on Tables 21 and 22. Since 1980, the frequencies of older (1971 - 73) walleye cohorts have decreased dramatically while younger (1974 - 1976) walleye cohorts have become dominant (Fig. 34). Since 1979, the frequencies of older (1972 - 1974) whitefish cohorts have been decreasing while frequencies of younger (1975 - 1976) whitefish cohorts increased for 3 years and then decreased since 1981 (Fig. 35). Arithmetic plots of walleye and whitefish cohort growth curves revealed 2 methodological errors: 1) either the 1979 experimental walleye sample was overaged or the 1980 experimental walleye sample was underaged (Fig. 36) and 2) unexpected decreases in the mean body sizes of all cohorts from 1981 to 1982 were probably due to major changes in sampling locations from 1981 to 1982 (Figs. 36, 37; compare Fig. 1 to Fig. 1 from Lysack 1980a).

It was hypothesized that increases in fishing effort reflected by increases in numbers of commercial fishermen and total catches (Fig. 38, Table 23) would cause stocks of whitefish and walleyes to compensate by increasing their rates of growth, maturity and recruitment.

Table 21. Age-specific frequencies (%) of Cedar Lake walleyes and whitefish determined from experimental and commercial samples.

Species	Sample type	Year	Age (years)												
			2	3	4	5	6	7	8	9	10	11	12	13	14	15
Walleyes	experimental	1979		2.4	11.9	27.3	30.5	19.0	5.2	1.9	1.3	0.2	.3			
		1980		0.8	0.4	6.5	21.7	24.7	31.9	7.6	3.8	0.8	1.1	0.4		0.4
		1981	0.2	0.4	2.4	26.9	34.8	25.5	5.5	3.0	0.6	0.8				
		1982		0.9	4.0	5.5	16.2	34.6	26.9	8.6	2.1	0.6	0.6			
	commercial	1979			4.4	17.8	42.2	25.6	5.6	3.3					1.1	
		1980					3.2	25.1	32.7	24.7	11.2	2.8		0.4		
		1981				2.8	15.6	45.6	30.4	5.2		0.4				
		1982				0.8	12.4	51.2	32.0	2.4	0.8	0.4				
Whitefish	experimental	1979		5.6	10.4	28.5	31.9	17.4	4.2	2.1						
		1980		1.3	18.1	34.8	24.2	10.1	8.8	1.3	0.9			0.4		
		1981		2.4	10.2	27.0	32.3	19.2	4.8	2.4	0.6	1.2				
		1982	5.4	17.9	19.6	25	19.6	7.1	1.8		1.8				1.8	
	commercial	1979		0.6	12.1	38.8	30.3	12.7	4.2	0.6				0.6		
		1980		4.0	43.2	34.3	14.1	4.0	0.4							
		1981		14.4	63.6	19.2	2.4	0.4								
		1982		0.8	24.4	47.2	24.8	2.8								

Table 22. Age-specific mean lengths (mm) of Cedar Lake walleyes and whitefish determined from experimental and commercial samples.

Species	Sample type	Year	Age (years)												
			2	3	4	5	6	7	8	9	10	11	12	13	14	15
Walleye	experimental	1979		388	381	394	395	410	431	455	473	558	491			
		1980		230	250	338	364	397	411	450	488	534	503	460		532
		1981	290	350	355	394	423	543	487	497	552	561				
		1982		292	349	377	399	436	454	490	513	570	520			
	commercial	1979			396	416	411	433	460	439					582	
		1980					375	423	445	460	479	495		606		
		1981				390	403	418	430	450		508				
		1982				361	406	425	443	445	516	506				
Whitefish	experimental	1979		321	360	418	435	453	458	478						
		1980		309	352	402	451	468	496	506	569			609		
		1981		361	380	431	472	501	504	470	568	609				
		1982	289	323	387	424	445	483	472		508				558	
	commercial	1979		322	414	424	440	465	471	492				570		
		1980		345	358	383	429	437	440							
		1981		358	378	423	477	535								
		1982		322	380	418	422	475								

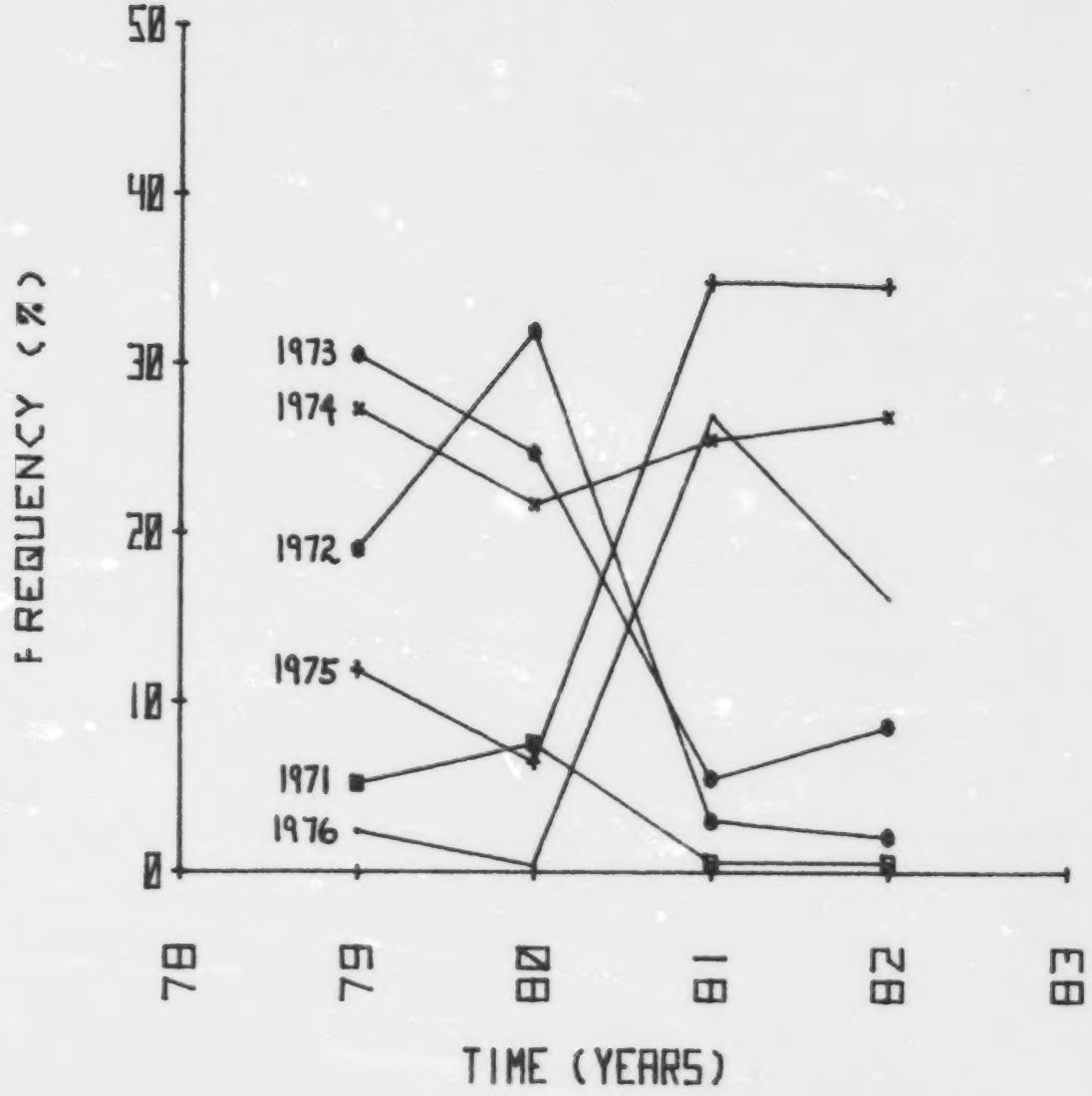

Fig. 34. Changes in age frequencies of Cedar Lake walleye cohorts.

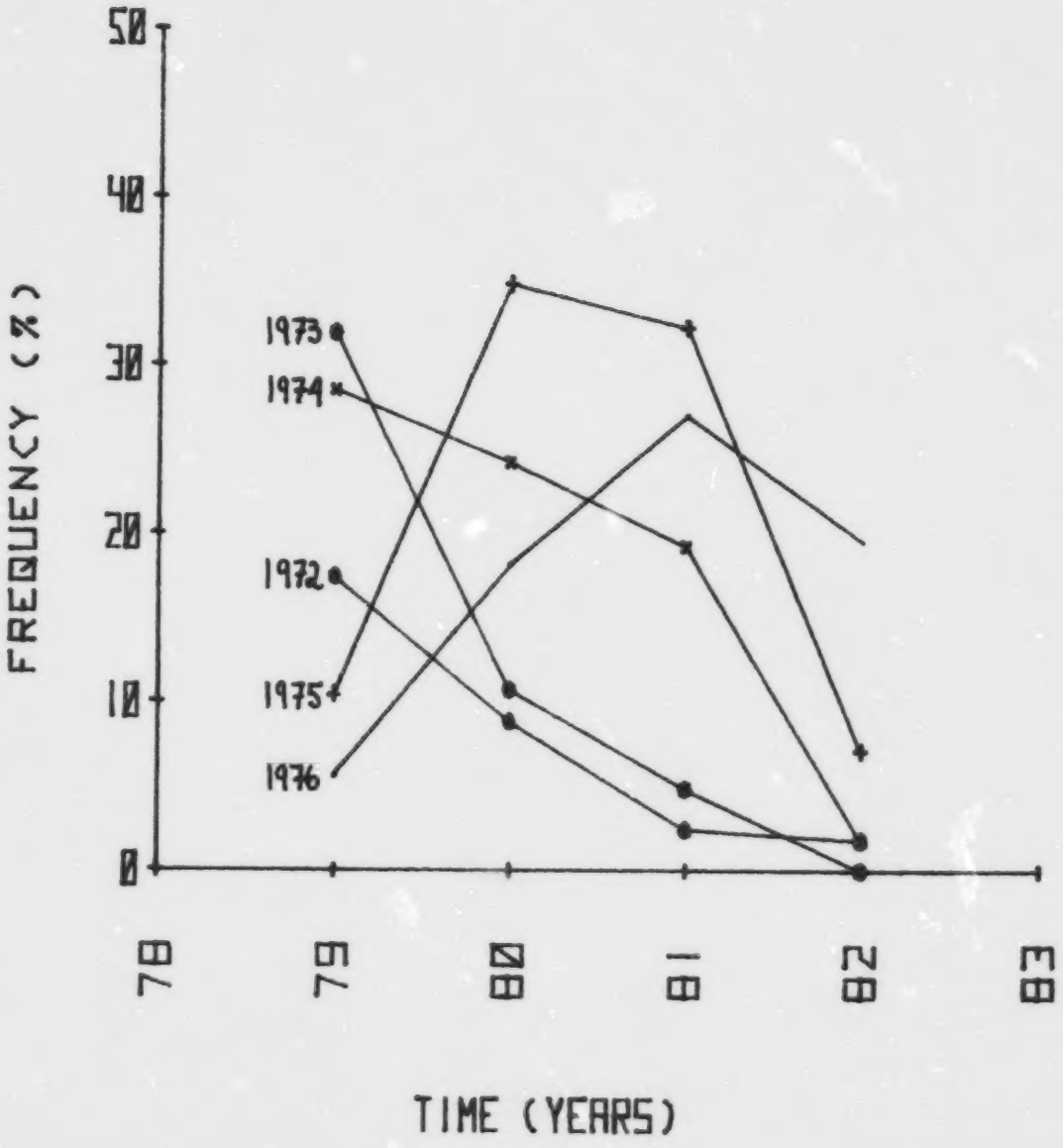

Fig. 35. Changes in age frequencies of Cedar Lake whitefish cohorts.

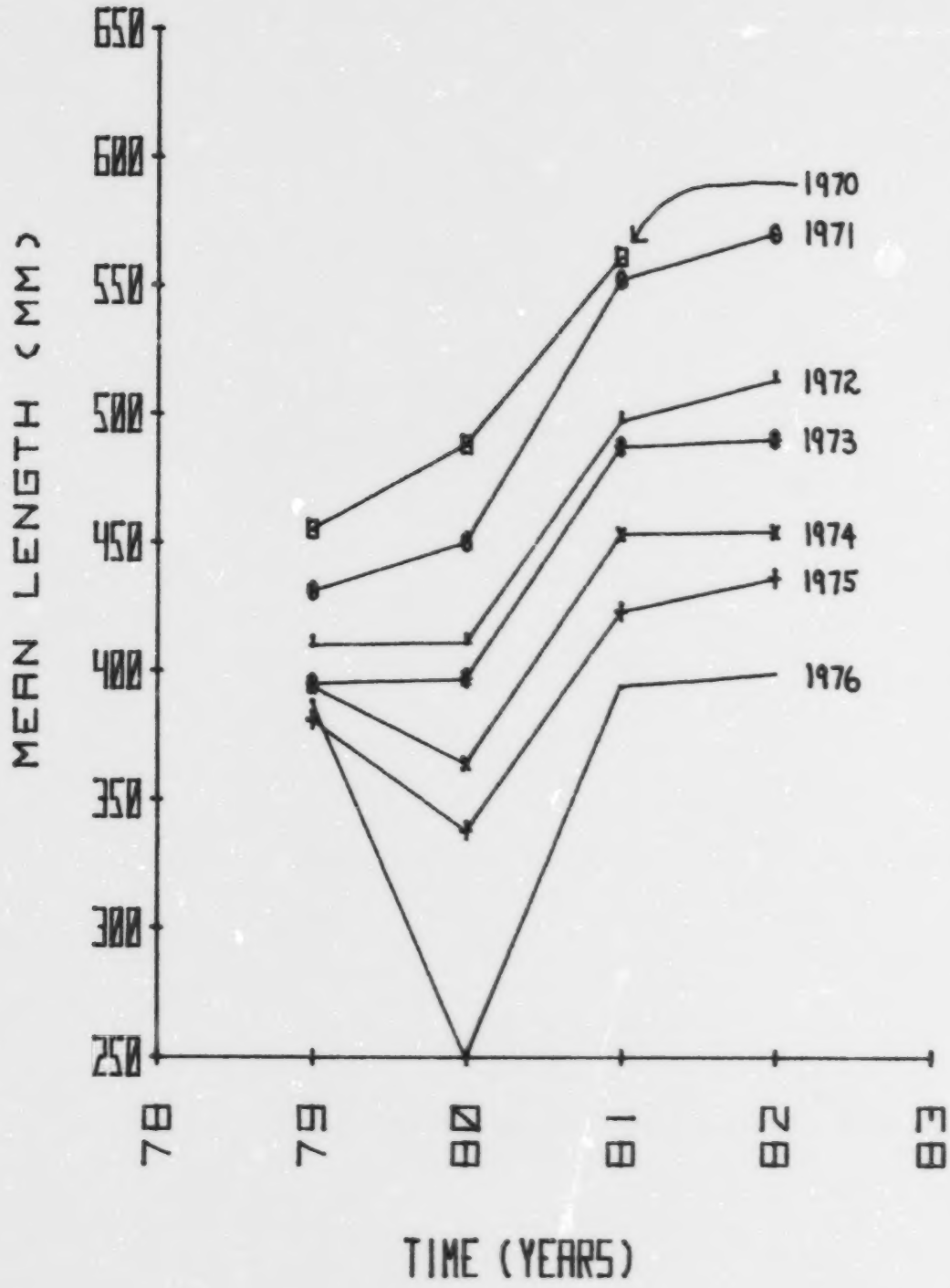

Fig. 36. Growth of Cedar Lake walleye cohorts.

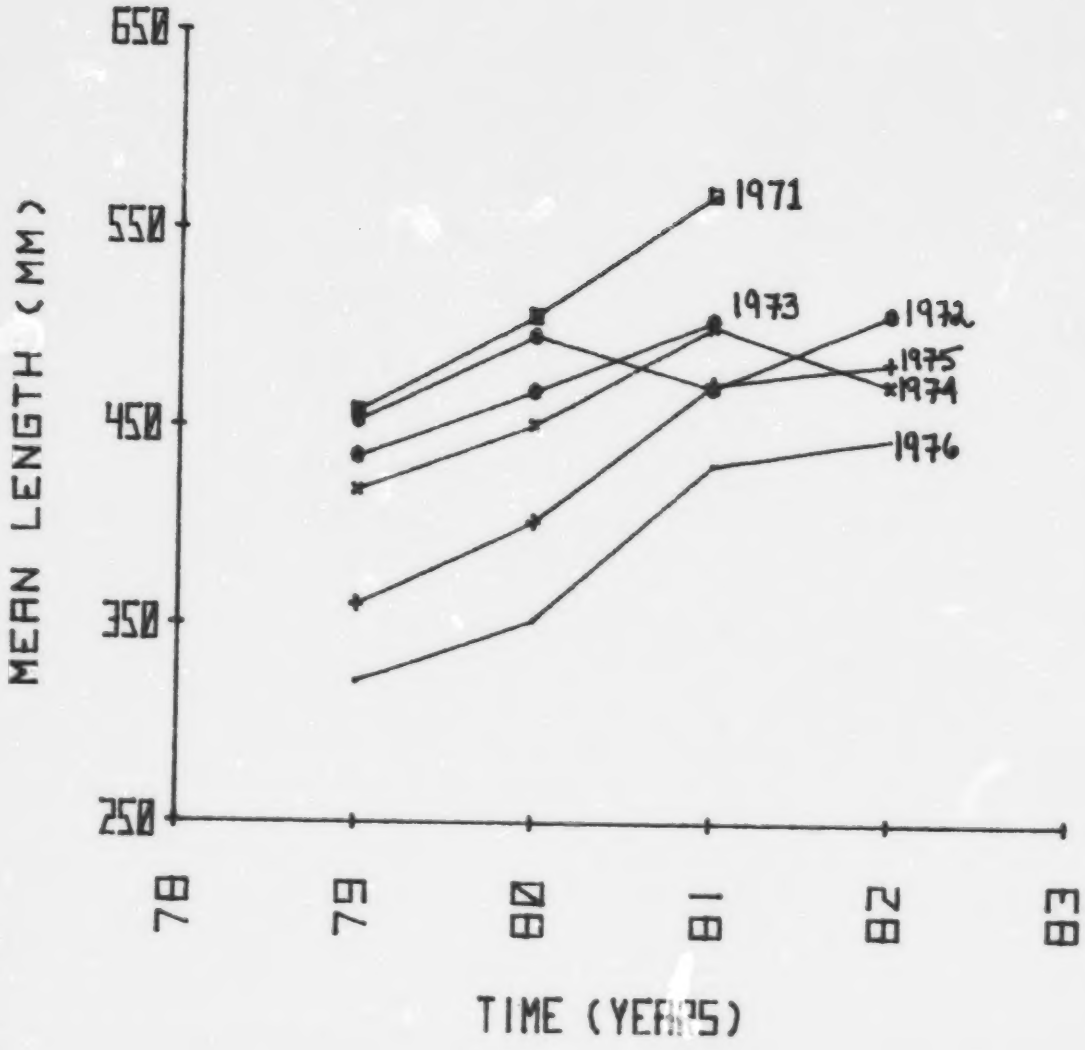

Fig. 37. Growth of Cedar Lake whitefish cohorts.

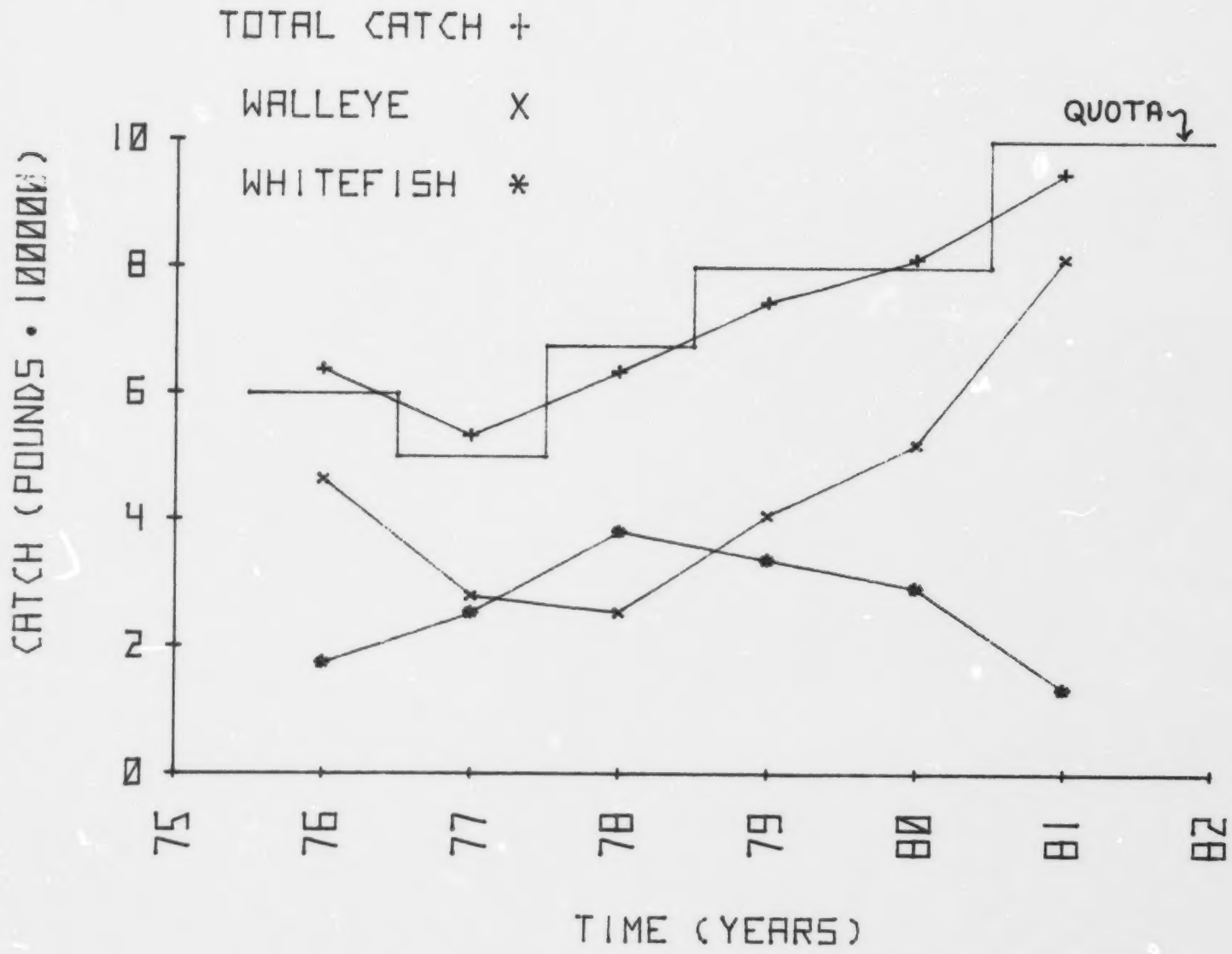

Fig. 38. Temporal changes in commercial catches and annual quotas on Cedar Lake.

Table 23. Catches of Cedar Lake fishermen (pounds) from 1976 - 1981.

	Year					
	1976	1977	1978	1979	1980	1981
Quota	600000	500000	675000	800000	800000	1000000
Total quota species	637493	532785	634994	744621	813396	948903
walleye	463783	279710	253380	407068	519875	814602
whitefish	173559	252902	381492	336967	292939	133762
sauger	17	107	7	440	454	373
goldeye	134	66	115	146	128	166
Total non-quota species	736353	946730	1051024	980922	986544	767339
pike	591008	636013	623235	663039	616171	492657
tullibee	145277	310481	427392	317325	369467	272779
perch	68	236	397	558	609	1903
Total quota & non-quota species	1373846	1479515	1686018	1725543	1799940	1716242
No. licenses	63-72	63-69	65-69	64-67	65-76	68-75
No. hired men	40	38	33	33	59	78
$\bar{x}$	107.5	104	100	98.5	129.5	149.5
Catch/man	12779	14226	16860	17518	13899	11480

From 1979 to 1982, the arithmetic (linear) growth rate of the Cedar Lake walleye stock has been increasing by 4.871 mm yr^{-1} ($F = 4.87$, d.f. = 1,2). The arithmetic growth rate of the Cedar Lake whitefish stock has been decreasing by 1.246 mm yr^{-1} ($F = .05$, d.f. = 1,2) (Fig. 39). This implies that the population growth rates of Cedar Lake walleyes and whitefish have not changed significantly since 1979 assuming that the linear growth model is appropriate. However, the use of exponential and von Bertalanffy growth models in describing the population growth regimes of Cedar Lake walleyes and whitefish has been more appropriate because these models have generally yielded higher correlation coefficients (Lysack 1980a, b). Plots of exponential growth rates of both species revealed non-significant changes from 1979 - 1982 (for walleyes $F = .59$, d.f. = 1,2; for whitefish $F = .22$, d.f. = 1,2) (Fig. 40). Omitting the aberrent 1980 data points resulted in a significant change in growth rates of walleyes ($F = 626.34$, d.f. = 1,1) but not for whitefish. Examination of the von Bertalanffy growth curves of both species from 1979 - 1982 did not reveal any temporal trends since aberrent annual changes in estimates of L_∞ obscured consistent changes in Brody growth coefficients (Table 24).

Another hypothesis concerning compensatory growth increases in response to increasing fishing effort is that the mean size of fish within each age class should increase with time and this increase should be more rapid within the age classes that have been

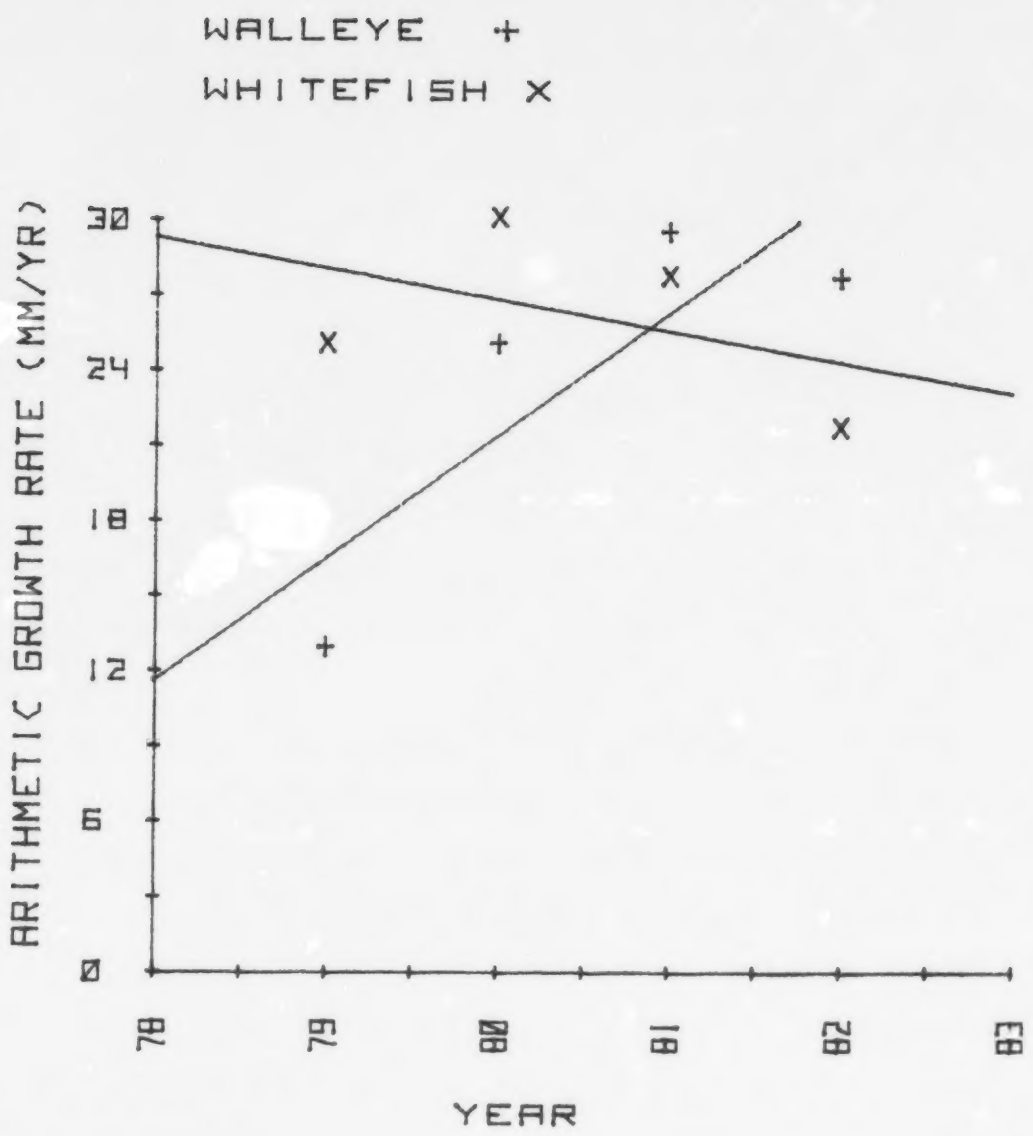

Fig. 39. Changes in the arithmetic growth rates of Cedar Lake walleye and whitefish stocks.

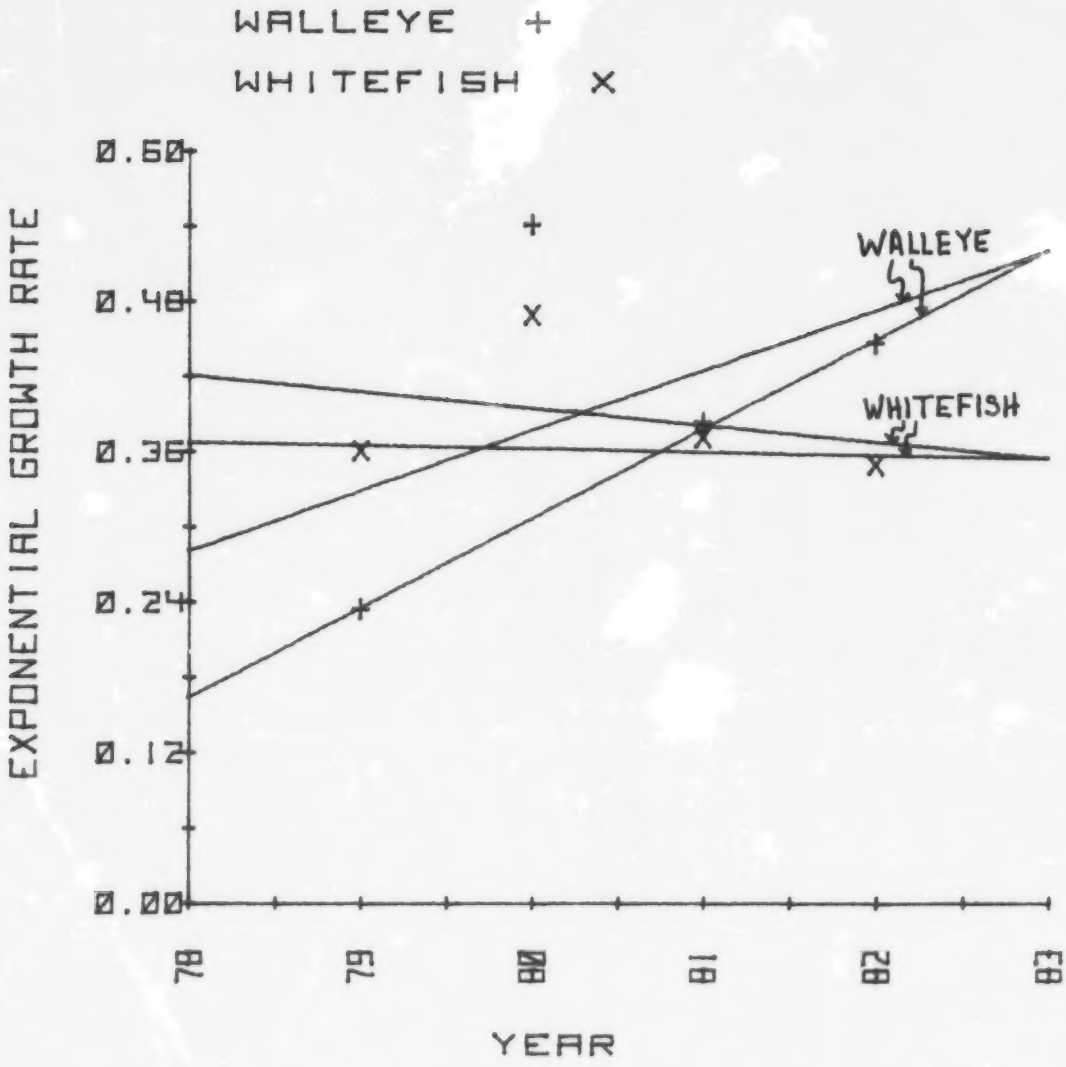

Fig. 40. Changes in exponential growth rates of Cedar Lake walleye and whitefish stocks.

Table 24. Growth curves of walleye and whitefish stocks in Cedar Lake from 1979 - 1982.

Year	Species	Growth curve type				
		Arithmetic	Exponential	von Bertalanffy		
				L_∞ (mm)	K	t_o
1979	Walleye	Length = 331.68 + 12.95 · age	Log_e length = 5.623 + .234 log_e age	-	-	-
	Whitefish	Length = 266.87 + 25.11 · age	Log_e length = 5.402 + .361 log_e age	502	.320	+.202
1980	Walleye	Length = 197.88 + 25.06 · age	Log_e length = 4.884 + .541 log_e age	515-550	.219-.328	+.954-2.198
	Whitefish	Length = 244.97 + 30.12 · age	Log_e length = 5.231 + .469 log_e age	578	.230	+.276
1981	Walleye	Length = 244.27 + 29.53 · age	Log_e length = 5.388 + .383 log_e age	590	.169-.246	-1.8 -+.14
	Whitefish	Length = 282.97 + 27.77 · age	Log_e length = 5.462 + .371 log_e age	529-607	.197-.425	+.695--1.403
1982	Walleye	Length = 232.27 + 27.70 · age	Log_e length = 5.208 + .446 log_e age	492-551	.255-.323	+.338--.425
	Whitefish	Length = 289.61 + 21.74 · age	Log_e length = 5.446 + .349 log_e age	487-524	.329-.440	+.08 --.299

recruited to the fishery. Slopes and correlation coefficients of curves plotted on Figs. 41 and 42 are listed on Table 25. Notice that deletion of the 1982 data produced more improvements in correlation coefficients of the whitefish curves than in the walleye curves. Also notice that the lowest slope for each species generally coincides with the modal age class of the commercial catch (Tables 21, 25). Most of the slopes listed on Table 25 were statistically non-significant. However the slopes were significantly related to age classes of walleyes ($F = 54.61$, d.f. = 1,5) but not of whitefish ($F = 7.16$, d.f. = 1,2) (Fig. 43). The steeper slope of the whitefish curve implies that whitefish respond to exploitation faster than walleyes.

The above growth analysis was confounded by two methodological sources of error. In 1980, walleye scales were improperly aged causing anomalies in age-specific estimates of mean sizes (Fig. 36) as well as in age compositions (Table 21, Fig. 34). In 1982 entirely new sampling locations in relatively unexploited areas of Cedar Lake caused a depression in age-specific mean length estimates of whitefish and especially of walleyes determined from experimental netting (Table 22).

The change in sampling sites also probably contributed to the major increase in mean age of walleye maturity from 1981 to 1982 (Table 26). When the 1982 maturity rates were deleted from plots of maturity rates over time (Figs. 44 - 46) slopes increased and correlation coefficients improved (Table 27). In fact, the relationship for whitefish changed from a negative to a positive

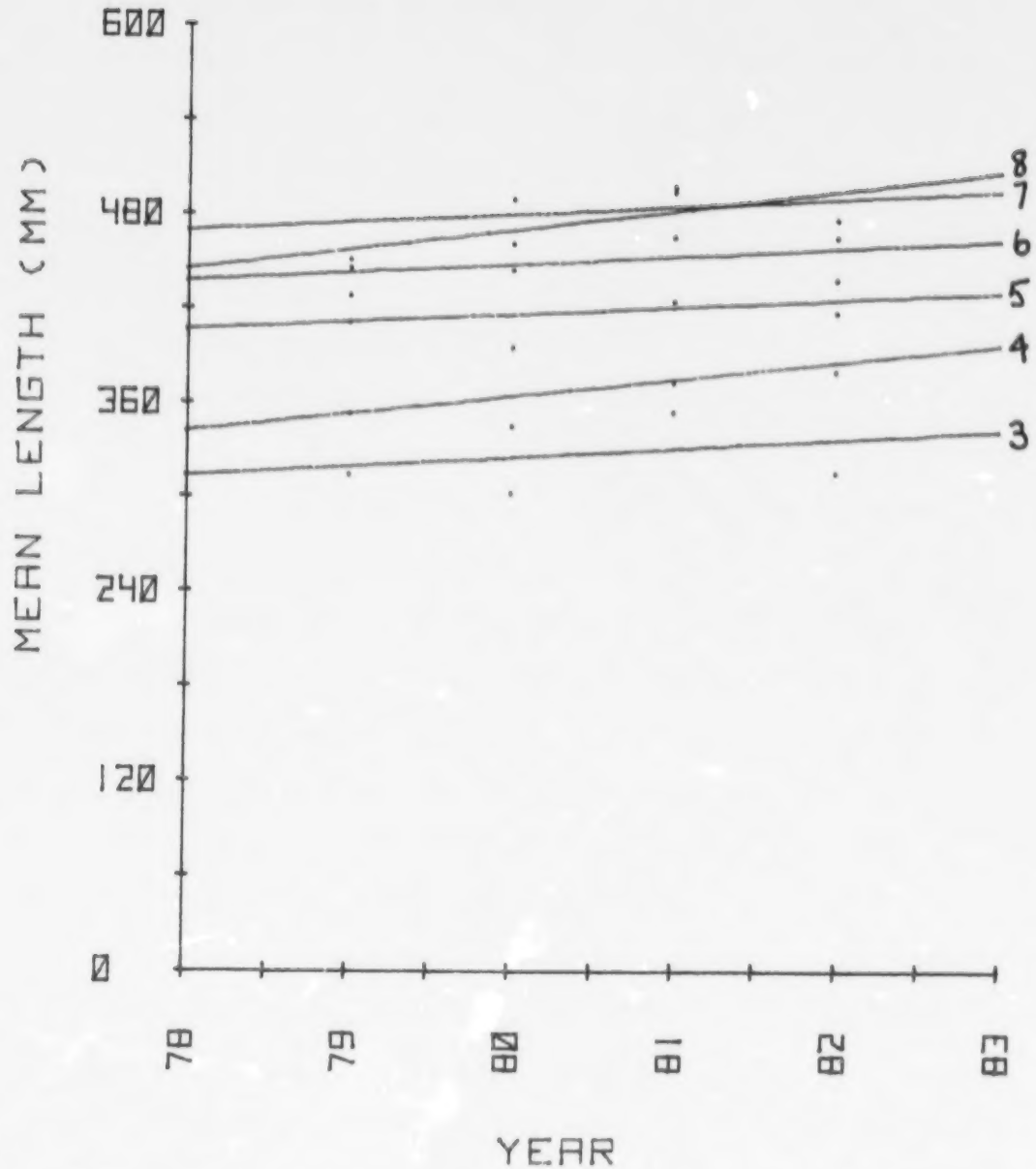

Fig. 41. Temporal changes in age-class specific body sizes of Cedar Lake whitefish.

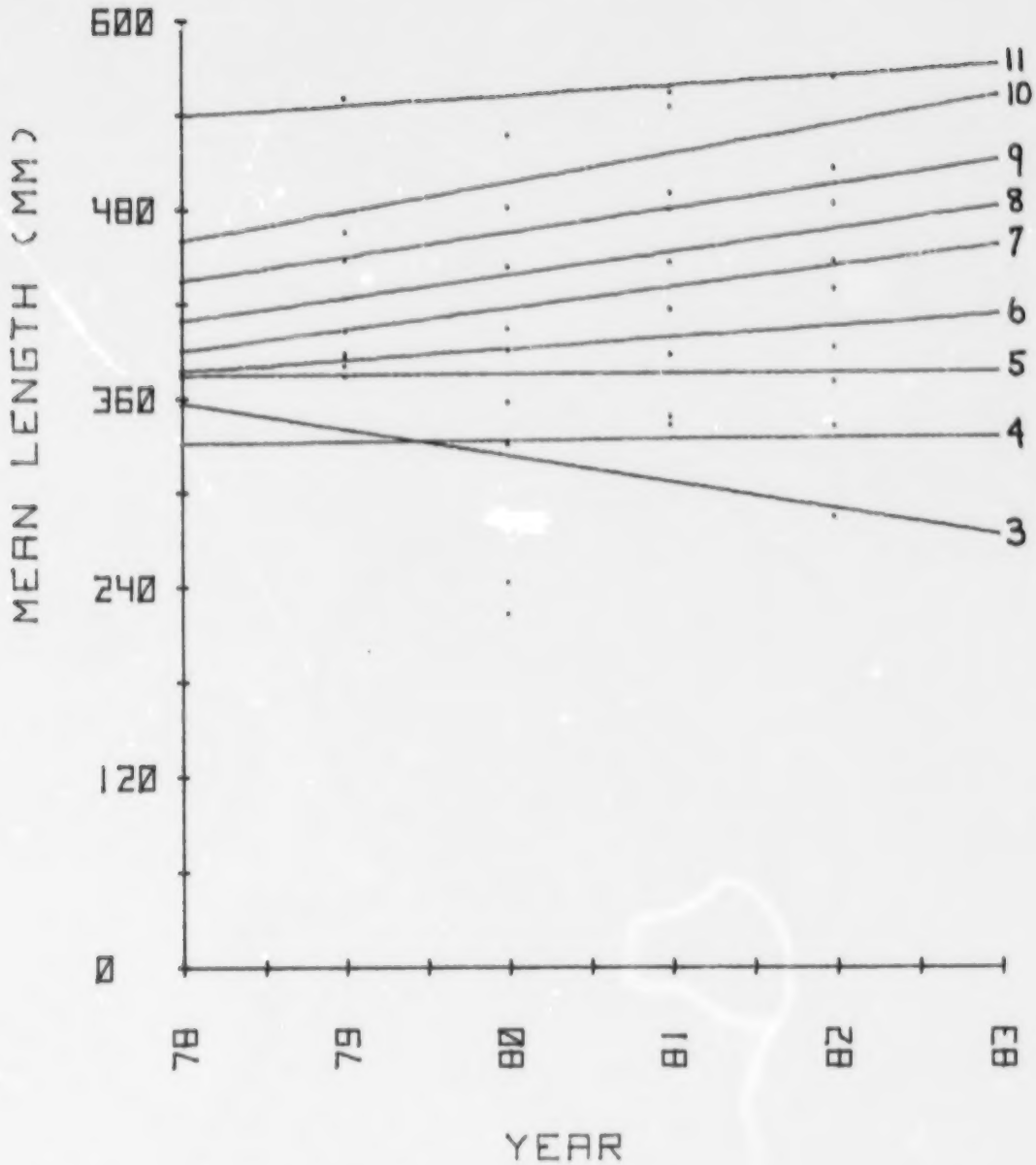

Fig. 42. Temporal changes in age-class specific mean body sizes of Cedar Lake walleyes.

Table 25. Age-class growth responses of Cedar Lake walleye and whitefish stocks.

Species	Age class	Data set			
		1979-1982		1979-1981	
		Slope	Correlation coefficient	Slope	Correlation coefficient
Whitefish	3	+ 5.8	.332	20	.735
	4	+10.9	.855	10	.693
	5	+ 4.7	.491	6.5	.447
	6	+ 5.1	.421	18.5	.997
	7	+12.3	.773	24.0	.977
	8	+ 5.0	.304	23.0	.936
Walleye	3	-16.8	.314	-19.0	.230
	4	+ .9	.020	-13.0	.187
	5	+ .5	.024	0	0
	6	+ 7.1	.378	14.0	.474
	7	+13.4	.686	21.5	.734
	8	+14.5	.574	28.0	.711
	9	+15.2	.820	21.0	.814
	10	+18.4	.688	39.5	.941

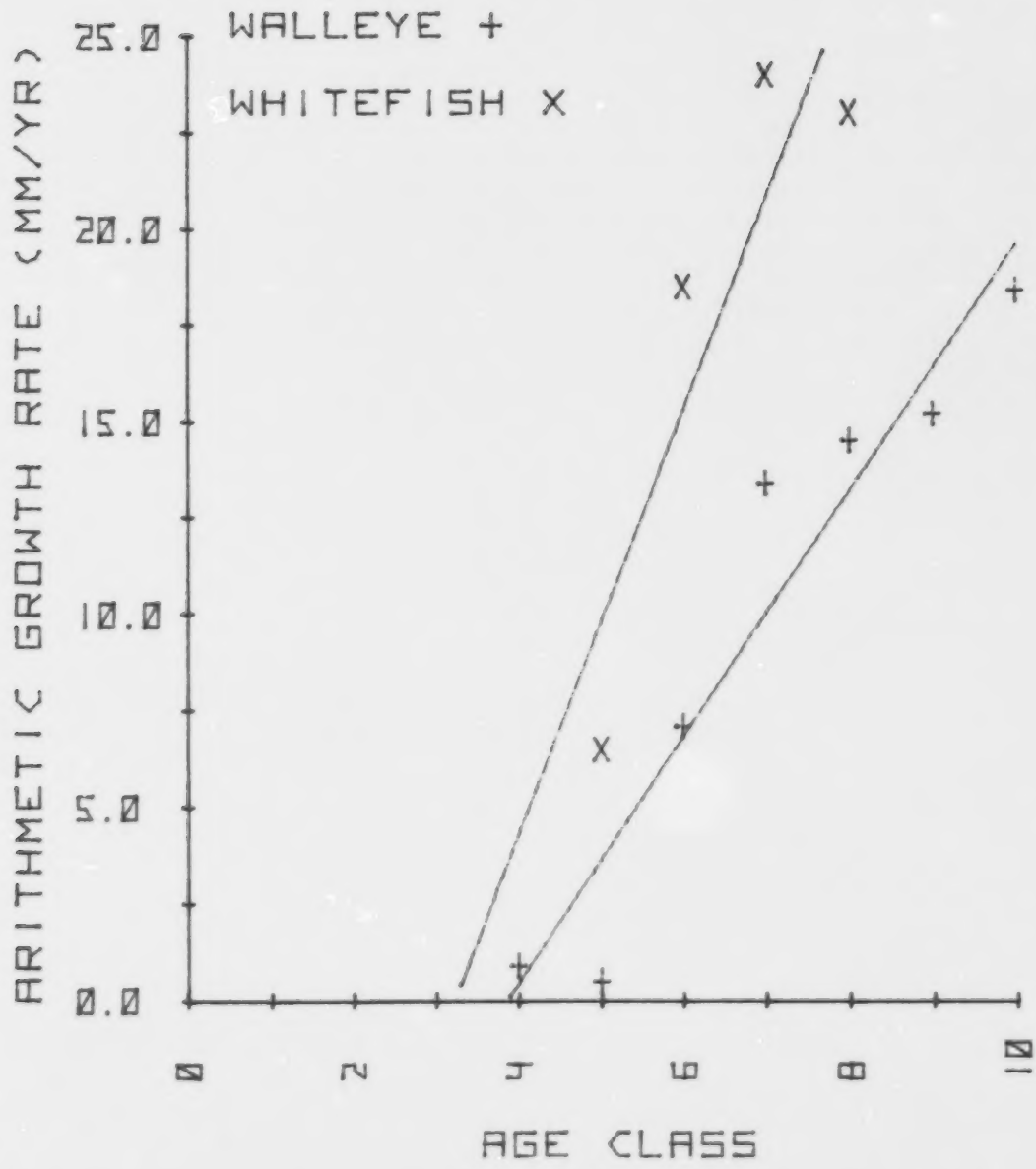

Fig. 43. Temporal changes in age-class growth responses of Cedar Lake walleye and whitefish stocks. The walleye curve was derived from 1979 - 1982 data while the whitefish curve was derived from 1979 - 1981 data.

Table 26. Maturity curves of Cedar Lake walleye and whitefish stocks.

Species	Year	Type	Maturity curve	Age at 50% mature
Walleye	1979	female	Y = - 3.12 + 0.59 X	5.32
		combined	Y = - 1.56 + 0.42 X	3.72
	1980	female	Y = -12.35 + 1.44 X	8.57
		combined	Y = - 7.68 + 0.97 X	7.95
	1981	female	Y = - 8.589 + 1.485X	5.78
		combined	Y = 5.452 + 1.101X	4.95
	1982	female	Y = - 6.785 + .968X	7.01
		combined	Y = - 3.678 + .636X	5.78
Whitefish	1979	female	-	-
		combined	Y = - 2.54 + .93 X	2.74
	1980	female	Y = -14.09 + 2.86 X	4.93
		combined	Y = -13.48 + 2.76 X	4.88
	1981	female	Y = - 5.830 + 1.493X	3.90
		combined	Y = - 9.142 + 1.903X	4.80
	1982	female	Y = - 6.835 + 1.675X	4.08
		combined	Y = - 4.085 + 1.074X	3.80

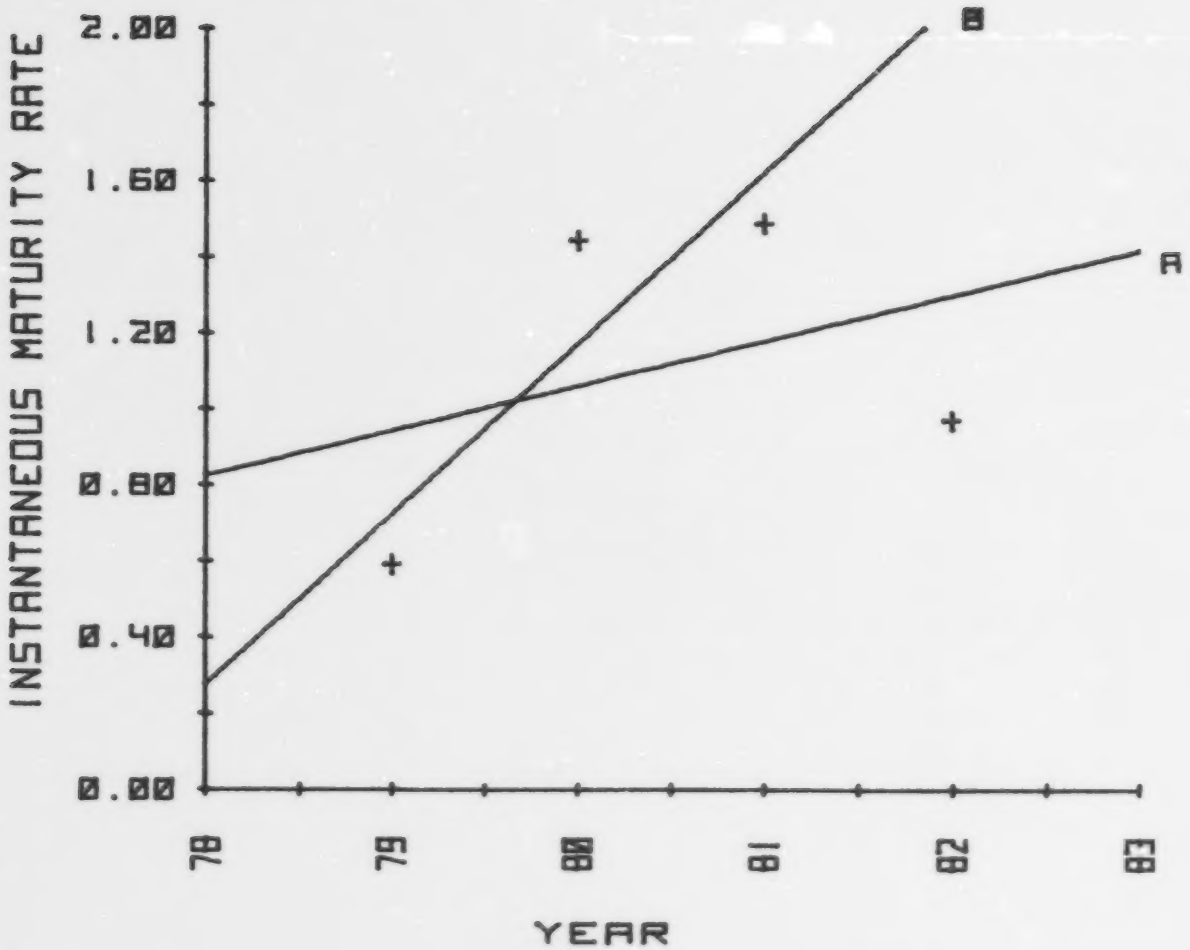

Fig. 44. Temporal changes in instantaneous maturity rates of female walleyes from Cedar Lake. Curve A includes all data points, curve B deletes the 1982 estimate.

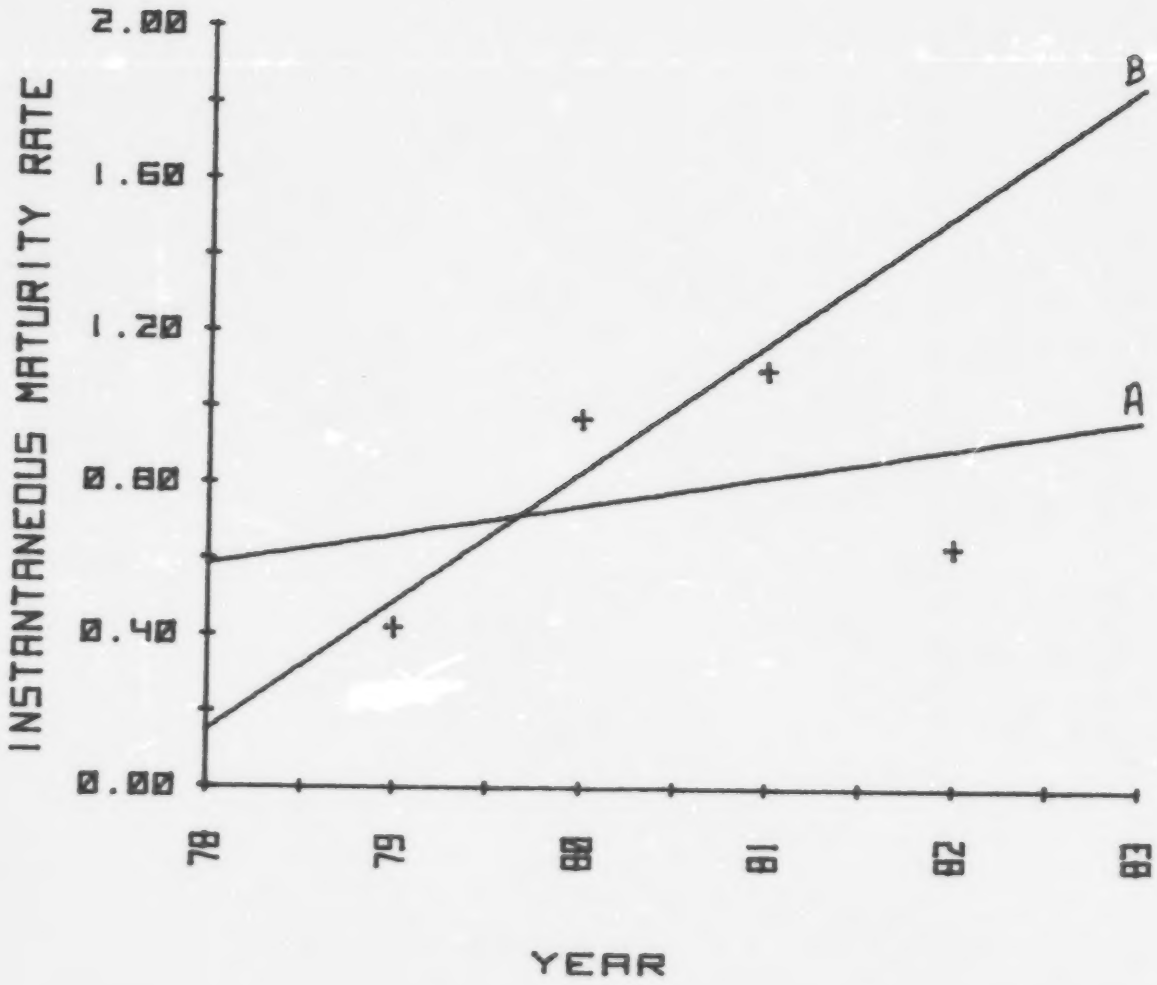

Fig. 45. Temporal changes in instantaneous maturity rates of Cedar Lake walleyes (sexes combined). Curve A includes all data points, curve B deletes the 1982 estimate.

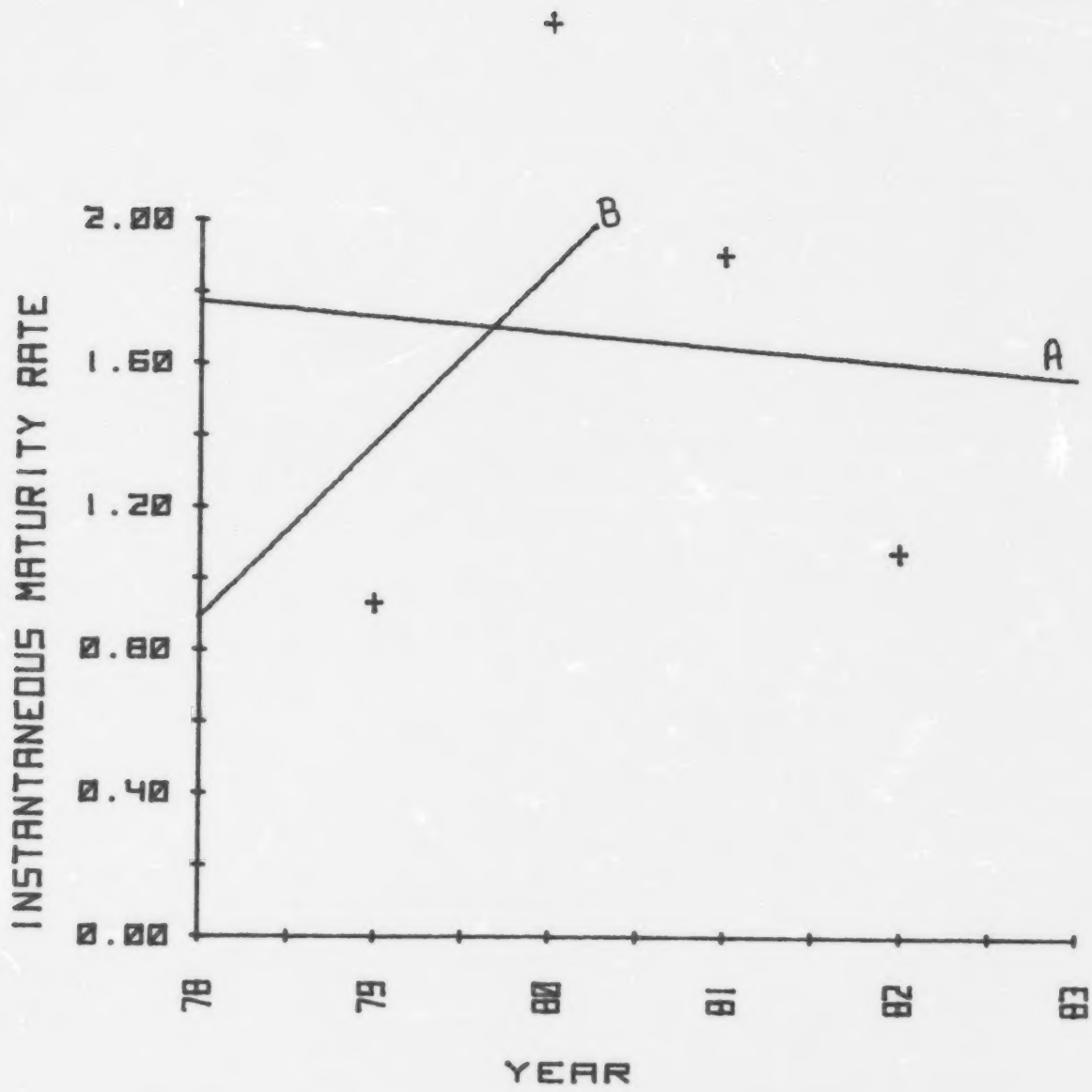

Fig. 46. Temporal changes in instantaneous maturity rates of Cedar Lake whitefish (sexes combined). Curve A includes all data points, curve B deletes the 1982 estimates.

Table 27. Temporal changes in instantaneous maturity rates of Cedar Lake walleyes and whitefish.

Species	Type	Data set					
		1979-1982			1979-1981		
		Equation[+]	R	F ratio and d.f.	Equation[+]	R	F ratio and d.f.
Walleye	female	Y = -8.37 + .118X	.359	.30(1,2)	Y = -34.63 + .448X	.887	3.71(1,1)
	combined	Y = -5.49 + .078X	.324	.23(1,2)	Y = -26.41 + .341X	.942	7.92(1,1)
Whitefish	female*	-			-		
	combined	Y = -5.09 - .043X	.065	.01(1,2)	Y = -37.06 + .487X	.531	.39(1,1)

[+] Y = instantaneous maturity rate, X = time (years)

* = non-significant curve in 1979 made this comparison impossible because only 2 data sets would be available in the second column of this table.

Table 28. Recruitment rates of Cedar Lake walleye and whitefish stocks determined from experimental netting and commercial sampling.

Species	Year	Source	
		Experimental netting	Commercial sampling
Whitefish	1979	.623	2.085
	1980	1.644	3.699
	1981	.877	3.896
	1982	.469	2.039
Walleye	1979	.846	1.130
	1980	.914	1.162
	1981	1.543	1.395
	1982	.870	2.079

one (Table 27). Temporal changes in maturity rates of both species were not statistically significant.

It was hypothesized that the slopes of ascending limbs of catch curves may provide relative estimates of recruitment rates. Slopes of ascending limbs of catch curves determined from both experimental netting and commercial sampling increased from 1979 to 1981 and then decreased in 1982 (Table 28). For whitefish, this effect may have been due to the passage of the strong 1977 year class through the fishery.

CONCLUSIONS AND RECOMMENDATIONS

1. The value of maintaining a standardized sampling and analysis program from year to year cannot be overemphasized. Future programs should re-establish a sampling location near the islands in the northwestern area of Cedar Lake.

2. Examination of annual changes in parameters comprising the usual sorts of population growth curves does not have as much merit as analysing cohort growth curves or temporal changes in age-class specific mean body sizes.

Not only do population growth rates increase with increasing fishing effort, but age-class specific body sizes increase from year to year and increase with the degree of recruitment to the commercial gillnets. Whitefish stocks in Cedar Lake have responded faster and to a greater degree than have walleye stocks. This is probably an inherent biological characteristics. Most of the year-class and age-class analyses of growth were statistically non-significant because data sets have been collected for only 4 years. This emphasizes the importance of gathering and analysing standardized data sets for relatively longer durations than we

first anticipated.

3. Rates of growth, maturity and recruitment of Cedar Lake walleye and whitefish stocks have increased in a compensatory fashion as fishing effort has increased. The scope for this compensation is ultimately determined by energy and nutrient availability as well as the mesh sizes and total effort expended in the commercial fishery. Since Cedar Lake is a reservoir lake, declines in productivity of all trophic levels may occur in the future as ecological processes begin to re-stabilize.

4. Total catches in Cedar Lake have been steadily increasing since 1977. Proportions of walleyes in annual catches have increased while proportions of whitefish have decreased. This is due to the value per weight differential between the two species. A lack of limited entry control on the Cedar Lake fishery has caused the catch per fisherman to decrease since 1979. From a strictly economic viewpoint, limited entry must be rigidly enforced in order to stabilize the amount of money earned per person. The economic benefit of a major increase in annual quota is easily dissipated by allowing minor increases in new individuals entering any fishery. For example, increasing the quota by 100,000 pounds and allowing 10 new people to enter the fishery does not maximize financial returns to the original people in the fishery and adds biological stress to stocks.

5. The recreational fishery potential of Cedar Lake remains totally untapped. This lake produces great numbers of large northern

pike which are attractive to many sports fishermen. If the Cedar Lake fishermen are genuinely interested in increasing their income, they should seriously consider this option.

6. The management agreement struck between the Cedar Lake fishermen and the Department of Natural Resources in 1980 stating that the annual quota and harvest would remain constant at 1,000,000 pounds for five years has not proven to be a viable management tool.

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